# AN INVESTIGATION INTO THE ACCIDENT CAUSAL INFLUENCE OF CONSTRUCTION PROJECT FEATURES

by

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A thesis submitted in partial fulfilment of the requirements of the University of Wolverhampton for the degree of Doctor of Philosophy (PhD)

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# ABSTRACT

The United Kingdom (UK) construction industry is one of the worst industries in the UK in terms of health and safety (H&S) performance. Numerous injuries, deaths, dangerous occurrences and work related illnesses are reported annually in the industry, and these are associated with huge economic and social costs which make the need for H&S improvement inevitable. The pursuit of improvement has triggered studies into construction accident causation which have emphasised the need to pay attention to underlying accident causal factors which emanate from the pre-construction stage in order to have sustained improvement in H&S. Construction project features (CPFs), such as nature of project, method of construction, site restriction, procurement method, project duration, level of construction, design complexity, and subcontracting, which are organisational, physical, and operational characteristics of projects emanating from pre-construction decisions fall in this category of underlying causal factors. However, despite the significance of underlying causal factors to H&S, not much attention by way of research has been given to CPFs. As a result, insight into how CPFs influence accident occurrence, the degree of their inherent potential to influence accident occurrence (i.e. their potential to cause accident) and their associated degree of H&S risk (i.e. the likelihood of accident occurrence due to CPFs) remain elusive in the extant construction H&S literature. This research was thus undertaken to empirically investigate the mechanism by which CPFs influence accident occurrence and assess their degree of potential to influence accident occurrence and their associated H&S risk.

Adopting a mixed method approach, the accident causal influence of CPFs was investigated. Following a conceptualisation of *how* CPFs influence accident occurrence based on systems models of accident causation, a qualitative inquiry involving semi-structured interviews with experienced construction professionals was undertaken to provide empirical verification of the conceptualised view. Subsequent to the qualitative inquiry, a questionnaire survey was undertaken to elicit relevant data from experienced professionals in construction management roles to enable the assessment of the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. From the analysis of data, it was found that CPFs, emanating from pre-construction decisions, influence accident occurrence by their inherent introduction of certain associated H&S issues (which can be termed as *proximal accident factors*) into the construction phase of projects to give rise to accidents. There are also causal interactions between CPFs and the proximal factors which can reduce or increase the presence of proximal factors. CPFs have varying degrees of potential to influence accident occurrence which can generally be *high* or *moderate* and is influenced by: the extent to which their proximal factor(s) is common (in other words prevalent) within them; and the degree of potential of the proximal factor(s) to influence accident occurrence. Where CPFs apply on a project, they are generally associated with *medium risk* or *high risk*. Whereas with medium-risk CPFs some risk control measures would suffice in mitigating risk, with high-risk CPFs substantial measures are required. As a consolidation of the research findings, a toolkit, called *CRiMT*, has been developed. *CRiMT* provides H&S risk information regarding CPFs and it has the potential of assisting pre-construction project participants in managing the accident causal influence of CPFs from the early stage of project procurement.

In view of the findings, the accident causal influence of CPFs should thus not be ignored or underestimated in construction project delivery. Pre-construction project participants, especially those whose decisions determine CPFs, ought to take into consideration the H&S effects of CPFs when making decisions which determine CPFs. Also, pre-construction project participants ought to plan and implement commensurate risk control measures in the early stage of projects to eliminate or mitigate the H&S risk posed by CPFs.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

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# DEDICATION

This thesis is dedicated to my family, especially mum and dad, my fiancée, and all construction workers.

# CHAPTER 1: INTRODUCTION TO THE RESEARCH

## 1.0 INTRODUCTION

The UK construction industry is one of the most dangerous industries in the UK in respect of health and safety (H&S). Although statistics indicate a trend of H&S improvement in the industry, the industry still accounts for numerous deaths, injuries, dangerous occurrences and work related illnesses (Health and Safety Executive [HSE], 2011a). These H&S outcomes associated with construction accidents impose a huge cost on the industry (Pearce, 2003) and for the over two million construction workforce (ONS, 2011) all of whom are at risk, and indeed the wider society this is clearly unacceptable.

H&S is an important objective on construction projects (Office of Government Commerce, 2004) thanks to drivers such as legislation (e.g. the Construction (Design and Management) Regulations 2007 (CDM 2007) and the Health and Safety Offences Act 2008), efforts of the HSE in prosecuting offenders, and the realisation by organisations that their workforce is their most valuable resource (Fellows *et al.*, 2002). This has created the need to implement measures that will prevent accidents on construction sites. The identification of appropriate measures and the effectiveness of their application however rely on an in-depth understanding of factors influencing accidents on sites. To this end studies have been (and continue to be) undertaken to identify the causal factors in construction accidents (cf. Brace *et al*., 2009).

Within the same context of investigating causal factors in construction accidents, this study investigates the accident causal role of construction project features (CPFs). The study interrogates the mechanism by which CPFs influence accident occurrence, their degree of potential to influence accident occurrence and their associated H&S risk. This first chapter introduces the research. It presents the research background, study justification, key research questions, research aim, and objectives. The scope of the research, the research design and the contribution of the research to knowledge are also presented, followed by an outline of chapters. These provide a point of reference against which the outcome of this research can be assessed.

## 1.1 RESEARCH BACKGROUND

In spite of the socio-economic benefits derived from the UK Construction industry (cf. Pearce, 2003; ONS, 2011), the industry has persistently been one of the worst industries in the UK in terms of H&S performance (HSE, 2011a). Accidents are relatively commonplace on construction sites the results of which are human tragedies such as deaths, major injuries and over-3-day injuries (HSE, 2009a; HSE, 2011a). This implies that associated with these socio-economic benefits of construction is unwanted ‘cost’ in the form of economic costs such as fines and costs from prosecution, claims on employers, insurance, damage to buildings and equipment or vehicles, cost of health or expenditure on medical care, cost of investigation, and cost from disruption of construction processes and delayed progress (Kartam, 1997; Hughes and Ferrett, 2008). Beyond the economic costs are also social costs such as the pain and sufferings of the affected workers, and the emotional and psychological impacts caused to friends, families and co-workers of the affected workers (De Saram and Tang, 2005; Ikpe *et al.*, 2006). Evidently, these costs dent the reputation of the construction industry (Kartam, 1997) and are clearly unacceptable.

Although recent statistics show some improvement in construction H&S in the UK, the HSE and some safety experts have linked the improvement to the recession which has resulted in a downturn in construction activity (Hoyle, 2009; HSE, 2009b). Notwithstanding this potentially downturn-stimulated improvement the construction industry's unenviable H&S performance still persists and this has been challenged over the years by initiative and reports such as the Revitalising Health and Safety Initiative (Department of the Environment, Transport and the Regions, 2000) and the Rita Donaghy Report captioned, "One Death is too Many" (Donaghy, 2009). The poor H&S performance has also necessitated numerous studies aimed at identifying the causal factors in construction accidents in order that appropriate mitigation measures can be implemented (Whittington *et al.*, 1992; Suraji *et al.*, 2001; Haslam *et al.*, 2005).

In reporting causal factors in construction accidents, construction accident causation studies have emphasised the need to pay attention to underlying causal factors which are upstream of the project procurement process in order to have sustained improvement in H&S (Haslam *et al.*, 2005; Brace *et al.*, 2009). The need to focus on underlying causal factors is also reinforced by the fact that the pre-construction stage from which they emanate offers project participants the greatest opportunity to influence H&S on projects (Szymberski, 1997; Brabazon *et al*., 2000).

Construction project features (CPFs) being organisational, physical and operational attributes of construction projects, fall in this category of underlying causal factors as they emanate from pre-construction decisions to influence accident causation. Construction H&S literature reveals that CPFs such as the nature of project (demolition, new work, and refurbishment), method of construction, site restriction, project duration, procurement system, design complexity, level of construction and subcontracting contribute to accident occurrence (Egbu, 1999; Hide *et al.*, 2003; Chua and Goh, 2004; Hughes and Ferrett, 2008; HSE, 2009a).

However despite the established significance of root accident influences to accident causation, not much by way of research has focused on these features. H&S studies and reports have in the main made passing references to the accident causal role of CPFs, without a focussed in-depth investigation of this accident causal phenomenon. As a result detailed insight into the degree of potential of CPFs to influence accident occurrence (i.e. their potential to cause accident) and their associated H&S risk (i.e. likelihood of accident occurrence) remain elusive. For instance, reports in the literature suggest that some methods of project procurement (e.g. design and build and partnering) have lesser potential to influence accident occurrence than others (e.g. management contracting and traditional procurement) (Horbury and Hope, 1999; Brabazon *et al.*, 2000; Hide *et al.*, 2003). Also the extant literature suggests that unconstrained/adequate project duration has lesser potential to influence accident occurrence than constrained/tight project duration (Hide *et al.*, 2003). The insight given in the literature is thus simplistic in that it is only a comparative measure of the degree of potential of CPFs to influence accident occurrence which is even confined to CPFs of the same kind (e.g. a procurement method having lesser or greater potential to influence accident occurrence than another procurement method) and as such does not give a holistic view of the individual measure/degree of potential of a CPF to influence accident occurrence. This limitation is also replicated in the H&S literature in terms of the H&S risk evaluation associated with CPFs. For example pre-assembly construction is considered as having lesser H&S risk than traditional method of construction (McKay *et al*., 2002) and new work is considered as having lesser risk than refurbishment (Anumba *et al.*, 2006).

Aside the above limitation in the extant literature, another facet of the accident causal phenomenon of CPFs that requires clarity is the mechanism by which CPFs influence accident occurrence. Although literature is replete with several accident causation models, they often provide a generic view of how accidents occur (Suraji, 2001) and as such they do not specifically address any particular accident phenomenon. As these models can however be instrumental in providing some scope for understanding the mechanism by which CPFs influence accident occurrence they are worth examining in relation to the accident causal role of CPFs.

Clearly, the above limitations in the H&S literature regarding the accident causal influence of CPFs constitute knowledge gaps which warrant investigation as such knowledge is important for effective H&S risk management or accident prevention (Suraji *et al.*, 2001; Hughes and Ferrett, 2008) particularly from the early stage of project procurement. As indicated by Szymberski (1997) and Brabazon *et al.* (2000), the pre-construction stage holds the greatest influence on the H&S outcomes of projects as safety can be influenced to the greatest extent in the early phases of a project. Szymberski (1997) indicated that the ideal situation is for construction worker safety to be a prime consideration of the project planners and designers at the conceptual and preliminary design phases in the procurement process. The importance of the early planning of H&S in project procurement is also stressed by Sir John Egan (Strategic Forum for Construction, 2002), in the Office of Government Commerce Procurement Guide 10 (Office of Government Commerce, 2004), and in the Construction (Design and Management) Regulations 2007 (CDM 2007) which aims at integrating H&S into the management of projects from the design concept onwards (HSE, 2007b). By the knowledge of how CPFs influence accident occurrence, their degree of potential to influence accident occurrence, and associated H&S risk, pre-construction project participants would be equipped to effectively manage the accident causal influence of CPFs through pre-construction decision-making and H&S planning and as a result positively influence the H&S outcomes of projects.

It is against this backdrop that this research is being undertaken to further the existing body of knowledge on construction accident causation, in particular the accident causal influence of CPFs. From the above discussion the fundamental research questions which need answering in order to bridge the knowledge gaps are;

- How do CPFs influence accident occurrence?
- What is the degree of potential of CPFs to influence accident occurrence? and;
- What is the degree of H&S risk associated with CPFs?

## 1.2 AIMS AND OBJECTIVES

The aims of the research are thus to empirically investigate the mechanism by which CPFs influence accident occurrence and assess their degree of potential to influence accident occurrence and their associated H&S risk. To achieve the above aims, the study would pursue the following objectives:

1. Undertake a critical review of the state of H&S in the UK construction industry highlighting the H&S performance, challenges, some improvement efforts and the accident causal influence of CPFs.
2. Undertake a critical review of H&S risk management with the aim of identifying a suitable method for evaluating the H&S risk associated with CPFs.
3. Develop a conceptual model of the accident causal influence of CPFs and to develop a measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk.

4. Empirically verify the conceptual model and develop an instrument to collect and analyse data to determine the degree of potential of CPFs to influence accident occurrence and their associated H&S risk.
5. Consolidate the findings of the research by developing a simple H&S risk management toolkit which focuses on the accident causal influence of CPFs.
6. Validate the research findings and evaluate their industrial relevance to pre-construction H&S planning from practitioners' perspective.
7. Draw conclusions from the findings of the study to provide a basis for proposing implications for H&S practice and recommendations for further research.

## 1.3 SCOPE OF STUDY

The focus of this study is the UK construction industry. However, it is expected that the study will draw from studies on the construction industries of other countries. Construction accident causation is a complex and multi-faceted phenomenon involving several inter-related accident causal factors (i.e. proximate and root factors). The entirety of construction accident causation is not covered by this study. Due to the relative limited research focus on root causal factors in construction accidents, the research focuses on root causal factors which emanate from the pre-construction stage of project procurement. In particular, the research pays attention to the features of construction projects (i.e. the organisational, physical, and operational attributes) which emanate from pre-construction decisions and have persistently been associated with accident occurrence.

Any references to potential of CPFs to influence accident occurrence in this study should be taken to mean the potential to cause accident/harm. In assessing the degree of potential of CPFs to influence accident occurrence and their associated degree of H&S risk, the assessments are limited to the generic independent/individual degree of potential of CPFs to influence accident occurrence and H&S risk. The assessments are thus not resultant measures which take into account the effects of potential inter-causal relationships which transpire in accident causation. Also, since contractor personnel/professionals are usually those who experience or witness accidents, they are the main focus for data collection.

## 1.4 RESEARCH DESIGN

From the research questions, it is evident that they are laden with measurement/assessment. Positivism is noted for its adoption as a world view or lens when studies are interested in measurement/assessment of observation, phenomenon, or reality (Easterby-Smith *et al*., 2002). In this research, positivism was thus adopted as the overarching paradigm and that dictated a mainly quantitative inquiry which also implied a largely deductive reasoning for the study (Loose, 1993; Sutrisna, 2009). Within the overall positivist framework, an element of qualitative inquiry was incorporated to facilitate understanding of the mechanism by which CPFs influence accident occurrence. This resulted in an overall mixed method research design, in particular the sequential exploratory mixed method where a quantitative inquiry is preceded by a qualitative inquiry (Creswell, 2009). Creswell (2003) provides an example of a scenario in which this approach can be situated *viz*; where for instance the researcher wants to both generalise the findings to a population and develop a detailed view of the meaning of a phenomenon, the researcher may first explore generally in a qualitative manner to learn about what variables to study, and then study those variables with a large sample of individuals through the development of an instrument (e.g. a questionnaire) and subsequent administration to the sample. This research mirrors Creswell’s scenario and this demonstrates the suitability of this mixed method approach for the research. A brief description and a flow diagram (Figure 1.1) of the entire research process are presented below.

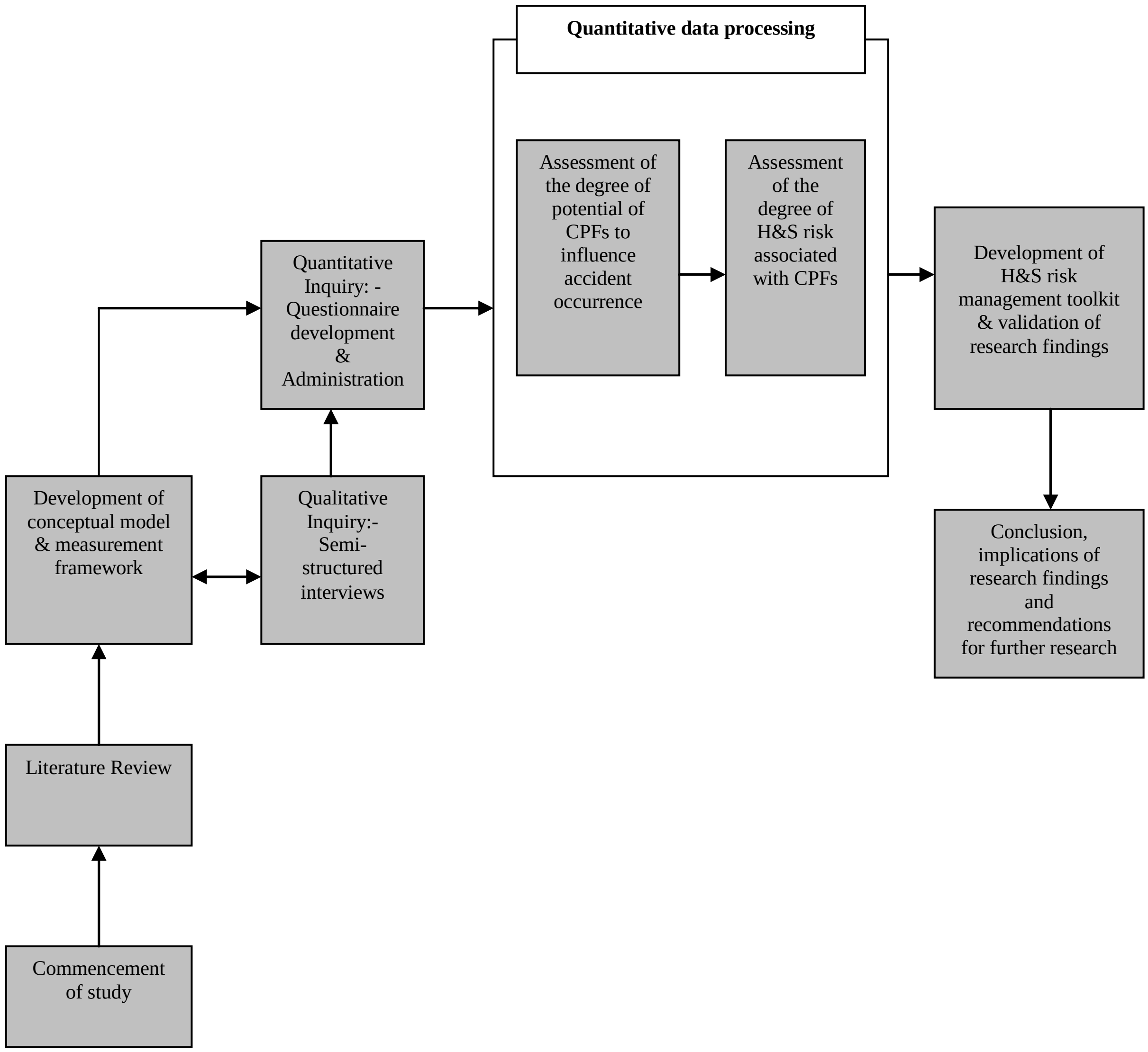



Figure 1.1: Overall research process

The study commenced with an in-depth review of the state of H&S in the UK construction industry highlighting the H&S performance, challenges to H&S improvement, efforts to bring about improvement, and the accident causal influence of CPFs. The review accentuated the role of CPFs in accident causation, pointing out the scope for further research in relation to how CPFs influence accident occurrence, their degree of potential to influence accident occurrence and their associated H&S risk. The in-depth review also focussed on H&S risk management and in particular methods of H&S risk assessment with the aim of identifying a suitable method for assessing the H&S risk associated with CPFs.

In line with deductive research, the literature review underpinned the development of a conceptual model of the accident causal influence of CPFs (i.e. how CPFs influence accident occurrence) and a measurement framework relating two key facets of the knowledge gap (i.e. degree of potential of CPFs to influence accident causation and their associated H&S risk) in a unified coherent manner. The model representing a conceptual formulation of how CPFs influence accident occurrence was verified empirically through a qualitative inquiry which involved in-depth semi-structured interviews with experienced construction professionals. The interview findings together with literature subsequently informed a quantitative questionnaire survey comprising five main steps: development of the survey instrument; pre-testing and revision of the survey instrument; sampling for main survey; administering the survey instrument; and analysis of the resulting data. The questionnaire survey provided the basis for the assessment of the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. The findings emerging from the quantitative assessment and the qualitative inquiry were consolidated by the development of a H&S risk management toolkit focussing on the accident causal influence of CPFs. Subsequently, the research findings were validated and their industrial relevance was evaluated from practitioners' perspective.

Taken together, the implementation of the sequential two-stage research strategy enabled the emergence of empirical realities which collectively addressed fully the research aims and objectives and hence the underlying research questions.

## 1.5 SUMMARY OF CONTRIBUTION TO KNOWLEDGE

The contribution of the research to knowledge is detailed in Section 11.3 and briefly presented below. The research has provided new insight into construction accident causation from the perspective of the accident causal role of CPFs, revealing how CPFs contribute to accident causation, their degree of potential to influence accident occurrence, and the degree of H&S risk associated with CPFs. With respect to how CPFs influence accident occurrence, this study has shown that CPFs, originating from pre-construction decisions by clients and their design and project management teams, influence accident occurrence by their introduction of certain associated H&S issues (which can be termed as *proximal accident factors*) into the construction phase of projects to give rise to accidents. In addition to this path of causation, the process by which CPFs influence accident occurrence could be marked by causal interactions between CPFs and proximal factors which could reduce or worsen the presence of the proximal factors they introduce. Concerning the degree of potential of CPFs to influence accident occurrence this research has shown that CPFs generally have a *moderate* potential or a *high* potential to influence accident occurrence (i.e. a fair potential or severe potential to cause harm in terms of the H&S of workers) which is influenced by: the extent to which their proximal factor(s) is common/prevalent within them; and the degree of potential of their proximal factor(s) to influence accident occurrence. Where CPFs apply on projects, they are associated with *medium risk* (i.e. medium likelihood of accident occurrence) and hence requiring some risk control measures or they are associated with *high risk* (i.e. high likelihood of accident occurrence) and hence requiring substantial risk control measures.

As a result of the research undertaken, fifteen technical papers have been published in refereed international construction and H&S journals, conference and doctoral workshop proceedings. The full bibliographic details are provided in Appendix A.

## 1.6 STRUCTURE OF THESIS

The thesis consists of eleven chapters, organised as shown in Figure 1.2.

**Chapter 1** outlines the research background highlighting briefly the relevant research that has been carried out to date in the subject area, the knowledge gap that exist and the justification for this research. This chapter also presents the aim and objectives of the research, the scope of the research, the research design and the main contributions of the research to knowledge.

**Chapter 2** presents a review of the state of H&S in the UK construction industry. It highlights the H&S performance of the industry, the challenges to improvement and some of the improvement efforts.

**Chapter 3** presents an in-depth review of construction accident causation studies and the accident causal role of CPFs. It establishes the extent to which the accident causal phenomenon of CPFs has been explored in literature and consequently revealing the paucity of knowledge relating to how CPFs influence accident occurrence, their degree of potential to influence accident occurrence and their associated H&S risk.

**Chapter 4** continues the literature review by reviewing H&S risk management, and in particular methods of evaluating H&S risk to identify a suitable method for evaluating the H&S risk associated with CPFs.

**Chapter 5** presents the conceptualisation of the mechanism by which CPFs influence accident occurrence and also the development of a measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. Such a framework is necessary to map out in a clear and coherent manner the relationship between these two key facets of the knowledge gap under investigation.

**Chapter 6** outlines in detail the research design adopted for undertaking the research.

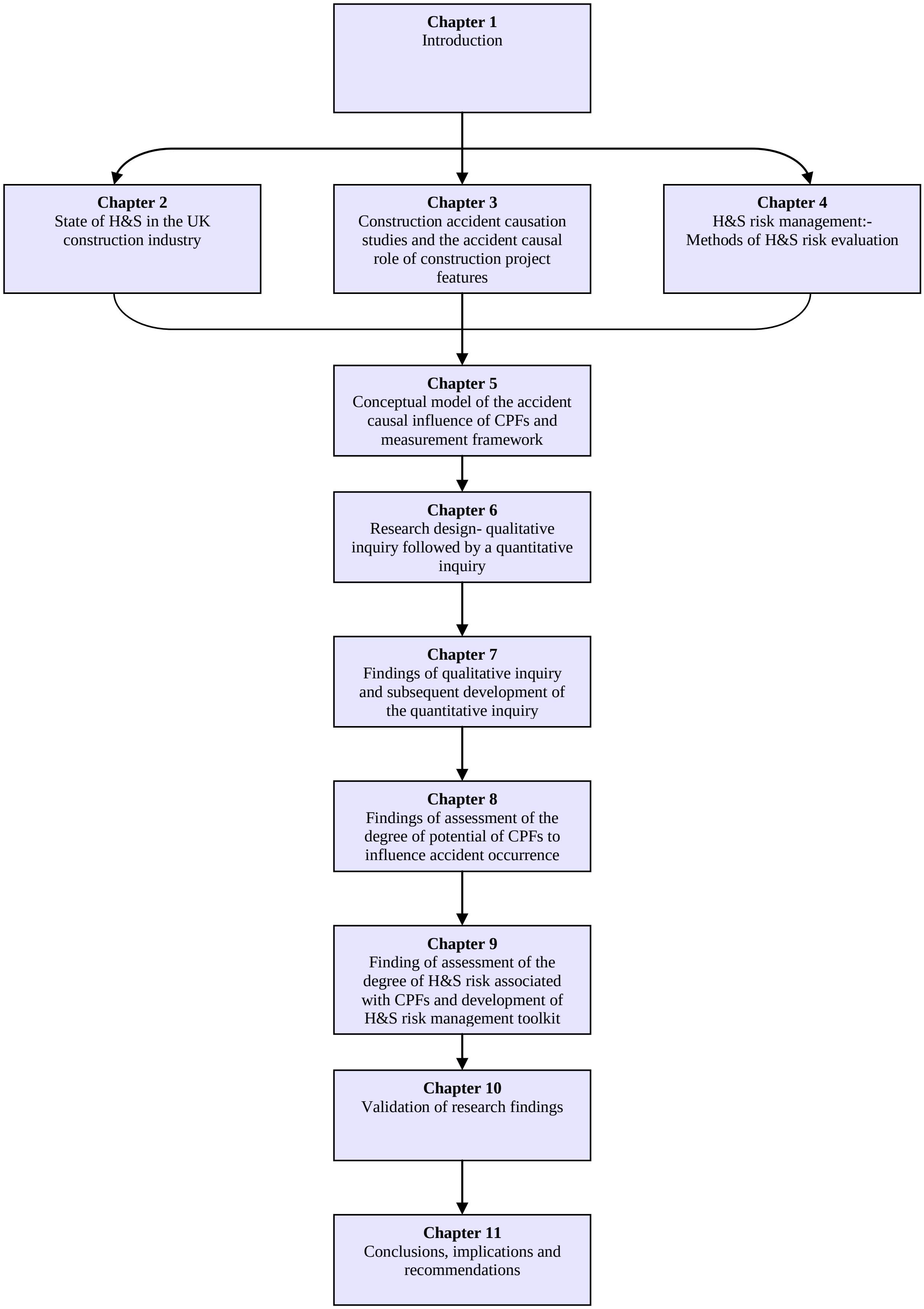



Figure 1.2: Organisation of thesis

A largely quantitative approach which is preceded by an incorporated element of qualitative inquiry is discussed including the argument justifying the choice of this sequential mixed method approach.

**Chapter** 7 presents the findings of the qualitative inquiry and the subsequent development of the quantitative inquiry.

**Chapter 8** presents the findings of the quantitative inquiry relating to the assessment of the degree of potential of CPFs to influence accident occurrence.

**Chapter 9** presents the findings of the quantitative inquiry relating to the assessment of the degree of H&S risk associated with CPFs. The chapter also presents the development of a H&S risk management toolkit as a consolidation of the entire research findings from both the qualitative and quantitative inquiries.

**Chapter 10** is devoted to the validation of the research findings and an evaluation of their relevance to pre-construction H&S planning from practitioners' perspective. The validation process together with its findings and conclusions is presented in this chapter.

**Chapter 11** finally draws the curtain on the research. It outlines the main findings of the research and the implications for industrial H&S practice. A reflection of the entire research process, the limitations of the research and recommendations for further research are also presented in this chapter.

## 1.7 SUMMARY

The UK construction industry is noted for its unenviable reputation of being one of the worst industries in UK in terms of H&S. The poor H&S performance has time and again triggered studies aimed at identifying the causal factors in construction accidents in order that appropriate mitigation measures can be implemented. In reporting causal factors in construction accidents, construction accident causation studies have emphasised the need to pay attention to underlying causal factors which emanate from the pre-construction stage to ensure sustained improvement in construction H&S. Despite the established significance of underlying causal factors to H&S not much by way of research has focussed on the underlying accident causal influence of CPFs which emanate from pre-construction decisions. As a result detailed insight into how CPFs influence accident occurrence, their degree of potential to influence accident occurrence (i.e. their potential to cause accident) and consequently their associated H&S risk (i.e. the likelihood of accident occurrence due to CPFs) remain unclear and thus constitute gaps in knowledge. Seeking to bridge these knowledge gaps, this study is being undertaken. This chapter has set out the aim and objectives of the study. The scope and the research design to be applied have been briefly outlined in addition to the main contributions of the research to knowledge.

In line with the structure of this thesis, the following chapter presents a review of the state of H&S in the UK construction industry. It highlights the H&S performance of the industry, the challenges to improvement and some of the improvement efforts.

# CHAPTER 2: STATE OF HEALTH AND SAFETY IN THE UK CONSTRUCTION INDUSTRY

## 2.0 INTRODUCTION

It is estimated that work-related accidents and illnesses contribute to 3.9 per cent of all deaths and 15 percent of the world's population suffer a minor or major occupational accident or work-related disease in any one year (International labour Organisation [ILO], 2005). In the UK, the construction industry faces a similar challenge with efforts being made to address the situation. This chapter presents an overview of the state of H&S in the UK construction industry. The chapter begins by defining health, safety and accident as applied in this research. It then presents the H&S performance of the construction industry and the associated costs. It also highlights the challenges to improvement and some of the improvement efforts. This review thus addresses in part the first research objective which is to undertake a critical review of the state of H&S in the UK construction industry to highlight the performance, challenges, improvement efforts and the accident causal influence of CPFs.

## 2.1 DEFINING HEALTH, SAFETY AND ACCIDENT

Before reviewing the state of H&S in the UK construction industry, it is important to define certain terminologies used in the domain of health and safety. Hughes and Ferrett (2008) define health as "the protection of the bodies and minds of people from illness resulting from materials, processes or procedures used in the workplace". Hughes and Ferrett (2008) also define safety as "the protection of people from physical injury". Health and safety are commonly used together and can thus be defined as protecting people from illnesses and injuries (i.e. harm) triggered by work-related conditions or activities (HSE, 2003), and this is adopted as the definition of H&S in this research.

Harm could result from an accident, which has also been defined in several ways (cf. Arbous and Kerrich, 1951; Stranks, 1994; Ridley and Channing, 2003). Arbous and Kerrich (1951) for instance define accident as an "unplanned event which, being the result of some non-adjusted act on the part of the individual (variously caused), may or may not result in injury". According to Stranks (1994) an accident is an unplanned and uncontrolled event which has led to or could have caused injury to persons, damage to plant or other loss. Ridley and Channing (2003) also define accident as "an unexpected, unplanned event in a sequence of events, that occurs through a combination of causes and results in physical harm (injury or disease) to an individual, damage to property, a near-miss, a loss, or any combination of these effects".

A slightly different definition is given by the HSE. The HSE (in Hughes and Ferrett (2008)) defines accident as an "unplanned event that results in injury or ill-health of people, or damage or loss to property, plant, material or the environment or a loss of a business opportunity". Whereas this definition only considers the occurrence of an adverse outcome as being the result of an accident, the other definitions consider the occurrence of an adverse outcome as well as the non-occurrence of an adverse outcome as being the result of an accident. The HSE (in Hughes and Ferrett (2008)) uses the term, near-miss, to distinguish an accident from an unplanned event which could have resulted in some adverse outcome. A common theme in all the definitions however, is that accidents are unplanned or unexpected events. For this research the HSE definition is first of all adopted as it is the official body for H&S matters in the UK. However, as the primary focus of this study is the ***health and safety of people*** (i.e. their protection against illness and injury) the definition of accident in this study focuses primarily on injury or illness as being the adverse outcome of an accident. Accident is thus considered in the context of this study as an unplanned event that results in injury or ill health of people (i.e. harm to people). The following sections now review the state of H&S in the UK construction industry.

## 2.2 HEALTH AND SAFEY PERFORMANCE OF THE UK CONSTRUCTION INDUSTRY

The significance of the UK construction industry to the nation's economy is very evident. The industry has over 200,000 organisations (including contractors, professional services, and suppliers) operating within it, employs over 2 million workers, and has an output in excess of £100 billion (ONS, 2011). The industry is also noted for its provision of the built environment which includes housing, educational, industrial, commercial, health, and infrastructure facilities.

Although all the industrial sectors in Great Britain together have a safety record which compares well to the safety records of other nations in Europe (HSE, 2011b), a critical look at the H&S situation in the UK construction industry reveals a worrying situation. The industry continues to be associated with an unenviable H&S performance as shown by H&S statistics such as Figures 2.1, 2.2, and 2.3. Figures 2.1, 2.2 and 2.3 show the annual fatalities rate, non-fatal major injuries rate and over-3-day injuries rate respectively for construction compared to other UK industries from 1981 to 2009/10 (provisional). Although generally there is a downward trend which indicates improvement, the construction industry continues to be ranked amongst the most dangerous industrial sectors. In terms of non-fatal injuries, the industry has even persistently registered the highest rate making it the worst industry with respect to non-fatal injuries.

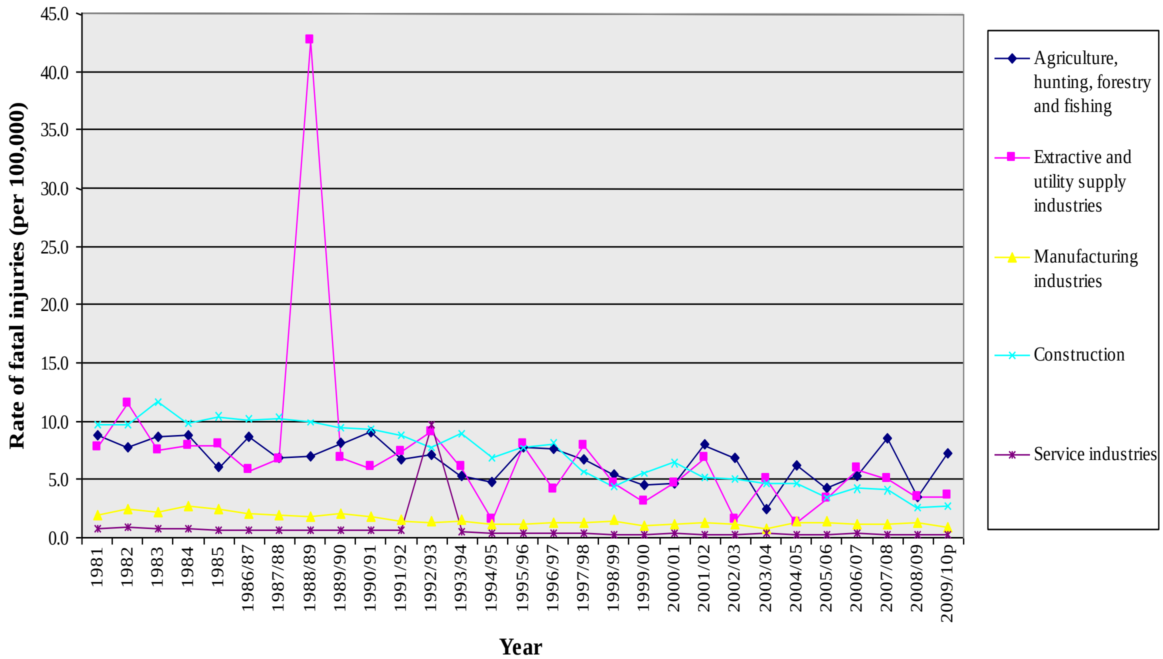



Figure 2.1: Fatal injuries rate for employees by industrial sector (HSE, 2011d)

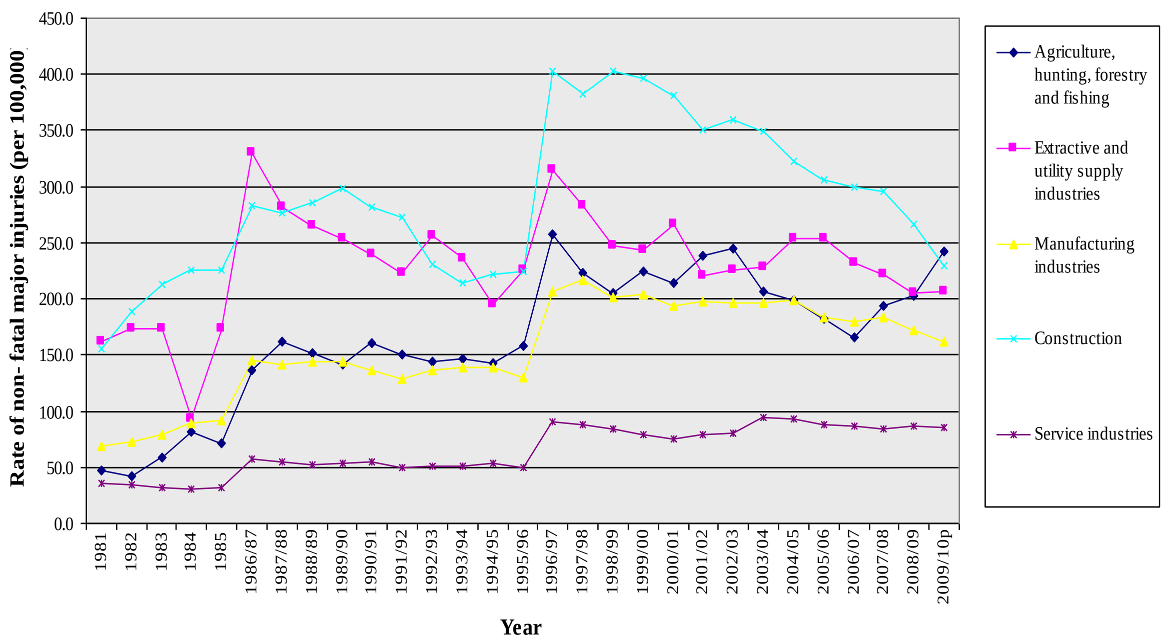



Figure 2.2: Non-fatal major injuries rate for employees by industrial sector (HSE, 2011d)

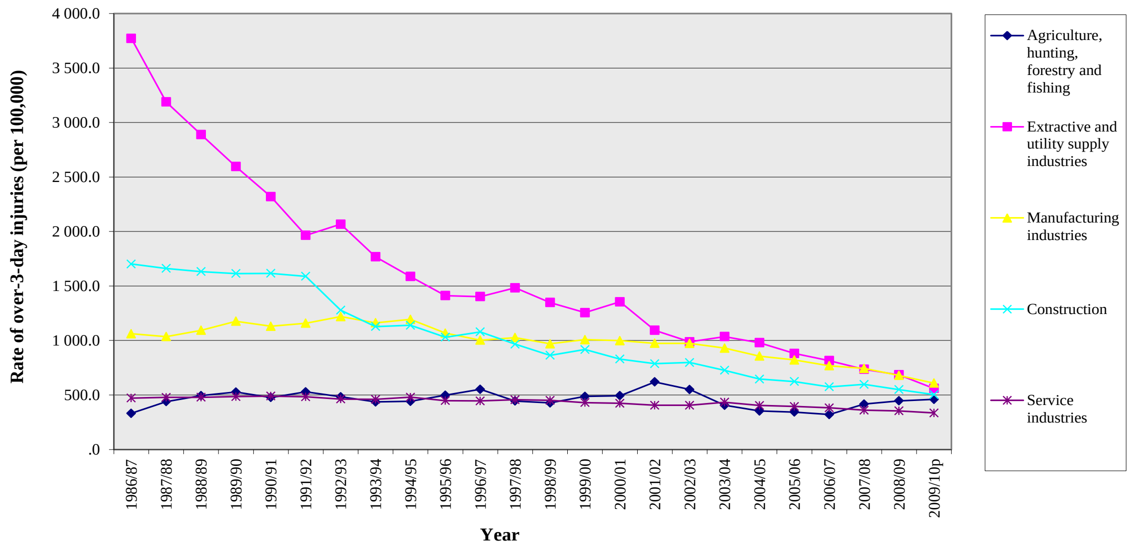



Figure 2.3: Over-3-day-injury rate for employees by industrial sector (HSE, 2011d)

Like the safety situation, the health situation in the construction industry is also worrying. Health problems such as stress, depression, anxiety, musculoskeletal disorders, dermatitis, cement burns, hearing loss, hand arm vibration syndrome and respiratory diseases are commonplace in the industry. Figure 2.4 which indicates estimated prevalence rates of self-reported illness from 2001/2002 to 2010/11 shows that the self-reported illness in construction has generally been persistently higher than that of all other industries. Figure 2.5 also shows estimated incidence rates for some categories of work related ill-health seen by The Health and Occupation Reporting Network (THOR) hospital specialists over the period 2007-2008 (HSE, 2011e). The figure demonstrates that in almost all the categories of work related ill-health the construction industry records a rate higher than all the other industries put together. This situation is particularly worse with categories such as diffused pleural thickening, asbestosis and mesothelioma where the construction industry records rates which are over 3 times the rates in all the other industries. The H&S performance of the industry as indicated by the H&S statistics is associated with significant costs and these are highlighted in the next section.

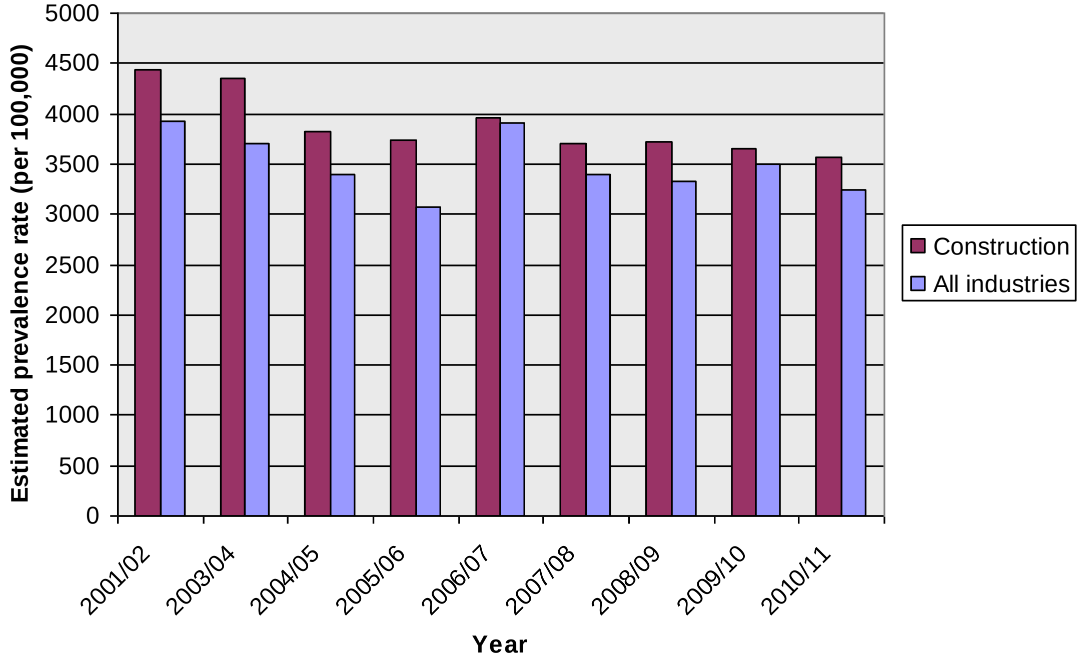



Figure 2.4: Estimated prevalence rates of self-reported illness caused or made worse by the current or most recent job, per 100 000 people working in the last 12 months (Adapted from HSE, 2011a)

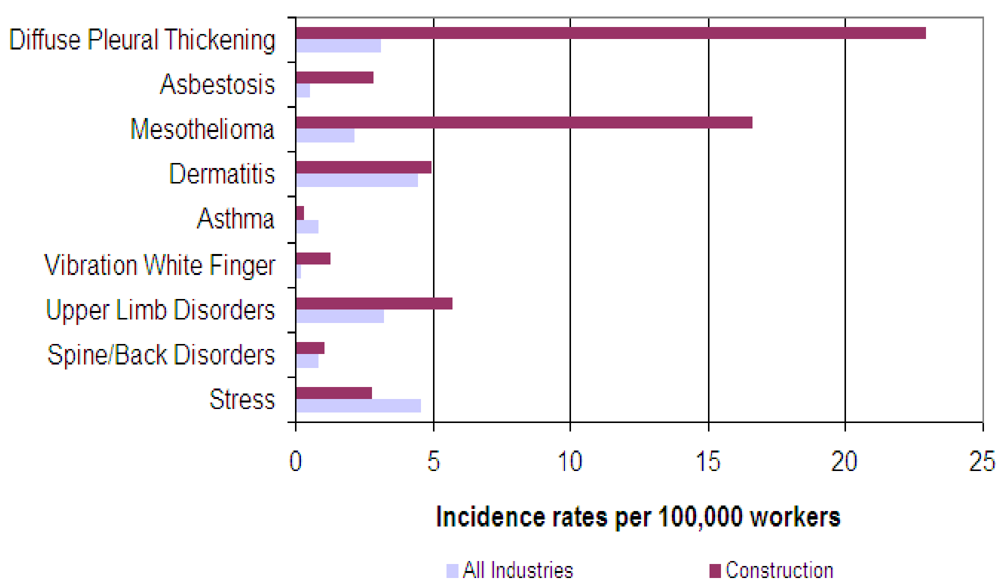



Figure 2.5: Estimated rates of work-related illness seen by THOR disease specialists per 100 000 workers in construction and in all industries, by broad disease category (HSE, 2011e)

### 2.2.1 The Cost of Injuries and Ill-Health

Pearce (2003) estimated that injuries and deaths in construction impose an annual cost of over ₤ 2 billion on the industry. The cost of injuries and ill-health can be considered in terms of direct costs and indirect costs (Hughes and Ferrett, 2008), and whereas some of these costs can be estimated in monetary terms, others such as the pain, suffering and psychological impact caused to victims, their families and friends are difficult to estimate monetarily. Among the direct and indirect costs are the items shown in Table 2.1.

Table 2.1: Direct and indirect costs of injuries and ill-health

| **Direct Cost** | **Indirect Cost** |
|---|---|
| Claims on employers and public liability insurance | Lowering of employee morale possibly leading to reduced productivity |
| Production and/or general business loss | First aid provision and training |
| Fines resulting from prosecution by the enforcement authority | Cumulative business loss |
| Sick pay | Determent of workers from entering the industry |
| Increases in insurance premiums | The recruitment and training of replacement staff |
| Any compensation not covered by the insurance policy | Loss of goodwill and a poor corporate image |
| Legal representation relating to prosecution | Accident investigation time and any subsequent remedial action required |
| Compensation claim | Production delays |
| Pain, suffering and psychological impact caused to victims, their families and friends | Extra overtime payments |
| Loss of enjoyment of life | Lost time for other employees |
| Medical cost | The economic impact on victim's family e.g. decrease in family income |

Source: Kapp *et al.* (2003), Pearce (2003), De Saram and Tang (2005), Hughes and Ferrett (2008), Mthalane *et al*. (2008), and Ikpe (2009).

These costs and the injuries and ill-health from which they arise dent the reputation of the construction industry and clearly demonstrate the need for H&S improvement. The construction industry by its characteristics however poses challenges to achieving H&S improvement. These characteristics and the challenges they pose are worthy of consideration and are therefore discussed in the following section.

### 2.2.2 Health and Safety Challenges of the Construction Industry

The construction industry by its features poses difficulties to improving H&S (Brabazon *et al.*, 2000; Bust *et al.*, 2008; Brace *et al.*, 2009). These characteristics include the: fragmented nature of the industry; little integration in the supply chain; large number of micro and small firms; and the increased presence of migrant workers. These are discussed in detail below.

#### 2.2.2.1 Fragmentation of the industry

The industry is highly fragmented, both in the workforce and professional disciplines. This fragmentation is evident in the considerable number of representative bodies for designers, contractors, suppliers and trades unions (cf. ONS, 2011). There is no one body that includes all the organisations involved in the construction industry in their representation, and there are some groups who are not represented at all in the bodies that do exist (HSE Construction Division, 2009). The highly fragmented nature of the industry coupled with the considerable variation and size of project-based work and the transient nature of works impacts on and acts as a barrier to health and safety management (Brabazon *et al.*, 2000; HSE Construction Division, 2009). In addition, from a regulatory view point, the multiplicity of sites means the HSE cannot visit every site (Bourn, 2004).

#### 2.2.2.2 Supply chain challenges

Despite the importance of the supply chain to project success, there is often little integration among the supply chain members over key decisions such as design (cf. Egan, 1998; Baiden, 2006; Hare *et al.*, 2006) which influence health and safety (Behm, 2005; Haslam *et al.*, 2005). Although the construction site is often where H&S risks are manifested it is not necessarily where effective risk control measures covering design, planning, and supply chain recruitment can be introduced to eliminate risk (cf. Szymberski, 1997). Once on site, contractors' options in eliminating or reducing risk may be limited (HSE Construction Division, 2009). Also the increasing technologies and specialisation in the industry has created a huge reliance on subcontracting in the industry which has consequences for H&S in terms of clarity of duties and working relationships, consistency of H&S practices among the workforce, competence, communication and co-operation among the workforce (Mayhew and Quinlan, 1997; Horbury and Hope, 1999; Arditi and Chotibhongs, 2005).

#### 2.2.2.3 Small enterprises

In most countries, small enterprises constitute a large majority of all businesses and account for a considerable share of all employees (Hasle *et al.,* 2009). Similarly in the UK construction industry, micro and small companies (i.e. firms employing less than 50 workers) constitute over 90% of construction companies (ONS, 2011). Although small construction companies employ 36% of the construction workforce, they account for 67% of fatalities amongst workers on construction sites (HSE, 2007a). They therefore account for a disproportionately large number of fatal injuries. Although the HSE does not collect data on major injuries according to the size of company or project, there is usually a close correlation between the number of fatal and major injury accidents (HSE, 2007a). Bomel Limited (2007) also reported that although competence varies widely across the industry, size of organisation is considered to be a key differentiator with large companies showing higher levels of competence on average than micro and small firms. Given the significance of competence to H&S (Bomel Limited, 2007; HSE, 2007b; Hare and Cameron, 2011) it is only consequential that micro to small construction companies account for 67% of all fatalities amongst workers on construction sites. It has also been reported in the construction industries of other countries (e.g. Italy, Spain and Taiwan) that workers of small firms are more likely to be injured than workers of large firms and also accidents in small firms are more likely to be severe than accidents in large firms (Chi *et al.*, 2004; Fabiano *et al.*, 2004; Camino López *et al.*, 2008). This situation has been attributed to the limited resources (management and financial) of small firms compared to larger firms which makes it difficult for small firms to apply more systematic approaches to health and safety management (Hasle *et al.*, 2009; Brace *et al.*, 2009).

#### 2.2.2.4 Migrant workers

In recent times, the UK construction industry has experienced an increase in migrant workers (Bust *et al*., 2008) with some estimates suggesting that migrant workers form around 8% of the construction workforce (cf. HSE Construction Division, 2009). Migrant workers face challenges in terms of their limited knowledge of UK health and safety systems, their ability to communicate with co-workers and supervisors and in gaining access to appropriate training (Dainty *et al.*, 2007). This presents challenges in ensuring the safety of this diverse workforce (Bust *et al.*, 2008; Fitzgerald and Howarth, 2009).

As shown, the above features of the construction industry pose difficulties in addressing its poor H&S performance. However, given the significant costs that are associated with the poor performance, efforts to bring about sustained improvement are inevitable. Among the prominent H&S improvement efforts are those highlighted in the following section.

## 2.3 HEALTH AND SAFETY IMPROVEMENT EFFORTS IN THE UK CONSTRUCTION INDUSTRY

The poor H&S performance of the construction industry has triggered efforts to redress the situation. Among these efforts are H&S legislation; industry wide initiatives such as the Latham (1994) and Egan (1998) reports; and H&S specific initiatives such as the Revitalising

H&S initiative, and construction H&S studies especially studies examining factors responsible for accidents from which work-related injuries and illnesses emanate.

### 2.3.1 The Health and Safety Legislation

Generally since the beginning of the 20th century, regulations have been put in place to control activities and address specific problems on construction sites (Horbury and Hope, 1999). The construction regulations of 1961 and 1966 which were made under the Factories Acts of 1937, 1948 and 1961 primarily provided H&S control of activities (Horbury and Hope, 1999). They however did not provide guidance on health and safety management which has a significant influence on H&S (cf. Bomel Limited, 2007). The laws were more concerned with the requirement for plant and equipment to be safe rather than the development of parallel arrangements for raising the health and safety awareness of employees (Hughes and Ferrett, 2008). These laws therefore tended to be reactive rather than proactive (Hughes and Ferrett, 2008).

Given the weaknesses of the H&S laws, in 1970 Lord Robens was tasked to review the provision made for occupational health and safety. Among the key recommendations of his report are as follows:

- the need for a single Act that covers all workers and also an Act that contains general duties which should influence attitudes;
- the need for emphasis on health and safety management and the development of safe systems of work; and
- the need for 'self-regulation' by the employer rather than reliance on prosecution in the courts (Hughes and Ferrett, 2008).

These recommendations led to the introduction of the Health and Safety at Work Act (HSWA) in 1974. The HSWA 1974 provides a comprehensive and integrated single piece of legislation dealing with the health and safety of people at work and the protection of the public from work activities (Hughes and Ferrett, 2008). The radical difference between the HSWA 1974 and all preceding H&S legislation is the emphasis the Act places on individuals and their duties rather than on the place of work (Joyce, 2001). The HSWA 1974 represents a key progression in the enhancement of H&S in that rather than the prescriptive approach which was adopted by the preceding legislations, the Act is based on principles designed to bring about a greater awareness of the problems associated with H&S (Joyce, 2001). The HSWA 1974 sets out general duties on employers who should ensure the H&S of their employees and members of the public, as far as reasonably practicable. The term "as far as reasonably practicable" implies that the duty carried out should be considered against the trouble, time and cost involved. The H&S duties imposed by the HSWA 1974 on the employer and other parties cover duties of:

- employers towards employees;
- employers and the self-employed towards persons other than their employees;
- people in control of non-domestic premises;
- manufacturers, designers, suppliers, etc. as regards articles and substances for use at work; and
- employees.

The Act also established the Health and Safety Commission and Health and Safety Executive, which recently under the Legislative Reform (Health and Safety Executive) Order 2008, have been merged into a unitary body called the Health and Safety Executive which is responsible for enforcement and proposing H&S regulations. Regulatory proposals from the HSE (formerly the HSC) to the Secretary of State are enacted into law. The HSWA 1974 is thus an Enabling Act/Primary Legislation which allows the Secretary of State to make further laws known as regulations (Secondary Legislation) without the need to pass another Act of

Parliament. Such regulations are supported by approved codes of practice (ACoP) and detailed guidance on complying with the regulations. The manner in which all these elements are related is illustrated in the legal framework in Figure 2.6 below.

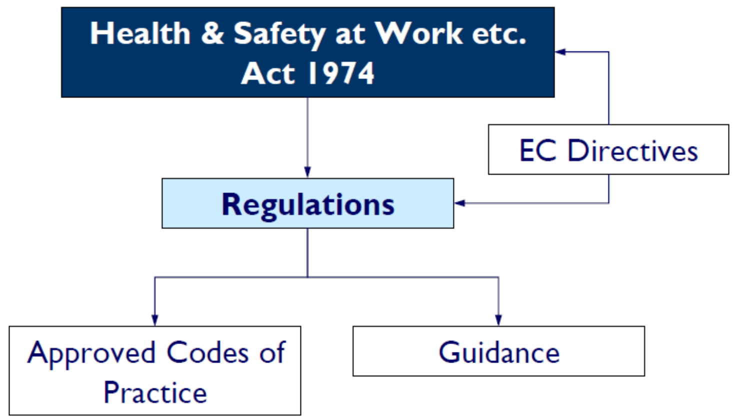



Figure 2.6: The H&S legal framework

As can be seen from this framework, sometimes the regulations are as a result of European Commission (EC) Directives. Through this legal arrangement numerous H&S regulations (Statutory Instruments) have emerged from the HSWA 1974 some of which are specific to construction and others covering all industries. These regulations have a common aim which is to improve H&S. Some of the regulations include those shown in Figure 2.7 below. It is important to highlight that aside the HSWA 1974 which is a major primary H&S legislation, there are other primary legislation such as the Corporate Manslaughter and Homicide Act 2007 and the Health and Safety (Offences) Act 2008.

It has been established that a considerable portion of the ability to positively and effectively influence site H&S resides at the planning and design stage of a project where construction professionals make crucial decisions (Szymberski, 1997; Brabazon *et al.*, 2000). Therefore whilst all the regulations are important for H&S improvement, the most prominent especially from a planning, design and management perspective could be considered to be the Management of Health and Safety at Work Regulations 1999 and the Construction (Design and Management) Regulations (CDM) 2007. These Regulations impose specific requirements for risk assessments and specific duties on construction professionals, and have a significant impact on the management of H&S in construction project delivery. These regulations are therefore examined below.

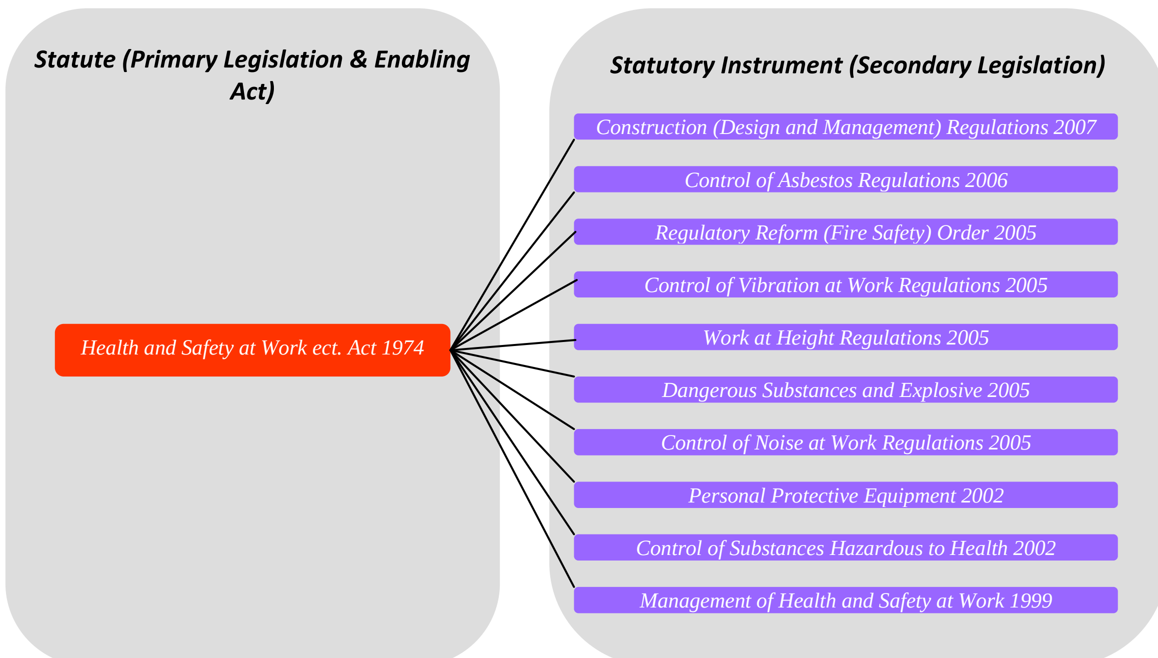



Figure 2.7: An illustration of examples of H&S legislation in the UK

#### 2.3.1.1 The Management of Health and Safety Regulations 1999

This Statutory Instrument was first introduced as The Management of Health and Safety at Work Regulations 1992. It was amended under The Management of Health and Safety at Work (Amendment) Regulations 1994 and finally re-enacted as The Management of Health and Safety at Work Regulations 1999. These regulations provide guidance on the general duties and obligations that employers have to their employees and third parties. They also contain guidance on the responsibilities that employees have to themselves and their colleagues.

The main requirement on employers and self-employed persons is to carry out a *risk assessment***,** covering both workers and others who may be affected by their work or business (HSE, 2000). The assessment should address the effect of their work activities and the condition of the premises. The assessment should identify how the risks occur and how they affect people. This information will affect the decisions on how to manage the risks, ensuring they are made in an informed, rational and structured manner and the action is proportionate to the risk. Employers who employ five or more employees should also record the significant findings of the risk assessment (HSE, 2000). The record should be retrievable for use by the employer in reviews and for safety representatives and other employee representatives and visiting inspectors. The Regulations state that the risk assessment should be "suitable and sufficient". This means that it should identify the risks due to, or in connection with the work, and it should be proportionate to the risk (HSE, 2000). For example, for small businesses with a few or simple hazards, no complicated processes or skills will be needed. However, for large and hazardous sites, the assessment will need to be thorough and thus may become complex (HSE, 2000).

The ACoP for the Management of Health and Safety at Work Regulations 1999 (HSE, 2000) and the HSE Guidance document INDG163 (rev2) (HSE, 2006a) provide practical steps on assessing risk. These steps are:

- identify hazards;
- identify who might be harmed and how;

- evaluate the risks from the identified hazards and decide on precautions;
- record the significant findings and implement measures; and
- review assessment and update.

Besides carrying out a risk assessment, employers also need to:

- make arrangements for implementing the H&S measures identified as necessary by the risk assessment;
- appoint competent people to help them to implement the arrangements;
- set up emergency procedures;
- provide clear information and training to employees; and
- work together with other employers sharing the same workplace.

#### 2.3.1.2 The Construction (Design and Management) (CDM) Regulations 2007

The Construction (Design and Management) Regulations first came into force as the Construction (Design and Management) Regulations 1994 (CDM 1994) in 1995 against the background of high accidents rates during the 1980's to provide a framework for H&S management in construction (HSE, 1996). The CDM 1994 was also in response to a Directive of the European Union in 1992 which is The Temporary or Mobile Construction Sites' Directive (92/57/EEC). The CDM 1994, with an emphasis on team work created specific roles for clients, planning supervisors, designers, principal contractors, and contractors with the common aim of achieving adequate levels of health and safety during construction (HSE, 1996). The CDM 1994 however underperformed in terms of competence assessment, fostering team work, and clarification of duties (Wright, 2003; HSE, 2006b; Bomel Limited, 2007). In 2007, the underperformance of the CDM 1994 finally yielded the Construction (Design and

Management) Regulations 2007 (CDM 2007) which seeks to address the shortfalls of the CDM 1994 so as to achieve improved levels of H&S in construction. The CDM 2007 was introduced with the key aim of integrating health and safety into the management of the project right from the early stages of projects (HSE, 2007b). The regulations placed new duties on clients, CDM Coordinators (formerly planning supervisors), designers and contractors to plan, coordinate and manage H&S throughout all stages of the construction project. Among the main differences between the CDM 1994 and CDM 2007 are:

- Regulations in CDM 2007 have been re-ordered to group duties together by duty holder and to show whether regulations apply to all projects or only notifiable projects.
- The requirements formerly in the Construction (Health, Safety and Welfare) Regulations 1996 have now been included within the CDM 2007.
- The role of the planning supervisor under the CDM 1994 has been replaced by the CDM coordinator role.
- The appointment of a CDM coordinator, principal contractor and preparation of a written health and safety plan are only required for notifiable projects.
- Duty holders cannot accept an appointment/engagement unless they are competent to carry it out.
- Assessment and demonstration of competence is simplified by the CDM 2007 ACoP, and everyone involved in a project has general cooperation and co-ordination duties.

The above differences show greater opportunity in the CDM 2007 to achieve improved competence assessment, team work and clarity of duties. A recent pilot study initiated by the HSE on the evaluation of the CDM 2007, suggests that the CDM 2007 is achieving these although further improvement is still required (Frontline Consultants, 2011). With these differences the CDM 2007 therefore stands to offer greater strides in construction H&S improvement than its previous version. A summary of the duties of duty-holders under the

CDM 2007 is given in the CDM 2007 ACoP (HSE, 2007b). As part of fulfilling their duties, some duty holders are required to produce or complete vital documents: F10 Notification Form, Construction Phase Plan, and H&S File. Details of these are also given in the CDM 2007 ACoP (HSE, 2007b).

### 2.3.2 The Latham and Egan Reports

Although not solely directed to H&S, the publication of ‘Constructing the Team’ by Sir Michael Latham (Latham, 1994) and ‘Rethinking Construction’ by Sir John Egan (Egan, 1998) have been acknowledged as important catalyst of H&S improvement (cf. HSE Construction Division, 2009) as both reports promoted client leadership, team work and a skilled workforce (i.e. competence) all of which are key elements of the Construction (Design and Management) Regulations (CDM) 2007 and are important to attaining health and safety improvements.

The Latham Report (Latham, 1994) was commissioned in a particularly difficult time for the UK construction industry as the economic recession was at its peak. Monetary policies were tightened and that affected the volume of work in the industry and increased competition. The general trend in the industry was for contractors and consultants to bid low for projects and make high claims during the execution phase. These practices increased conflicts and led to more adversarial attitudes within the industry. Consequently, many clients were dissatisfied with the performance of the industry (Baiden, 2006). Among the recommendations of the Latham report are:

- the clear establishment of Government as the best practice client which would set an example for other clients to follow;

- the production of a client's guide to briefing to assist all clients in understanding and being involved in the drawing up of briefs for projects; and
- the development of mechanisms for the selection of consultants which would allow both price and quality to be given appropriate considerations.

Following the Latham Report, the Egan Report (Egan, 1998) was published at a time when there was a strong Government support for financing public procurement. The promotion of a non-adversarial culture within the construction industry was also at its peak. Cultural changes within the industry had also increased concern for environmental issues resulting in the introduction of the "sustainable construction" concept. Poor health and safety records were widespread and the negative image of the industry resulted in low recruitment levels in the industry. Another key characteristic of the era was the development of cooperative project relationships. Many clients had thus moved from one-off to continued project partnering arrangement which laid the foundation for supply chain management (Murray, 2003). Egan (1998) proposed 5 drivers for change and targets for improvement which are shown in Figure 2.8.

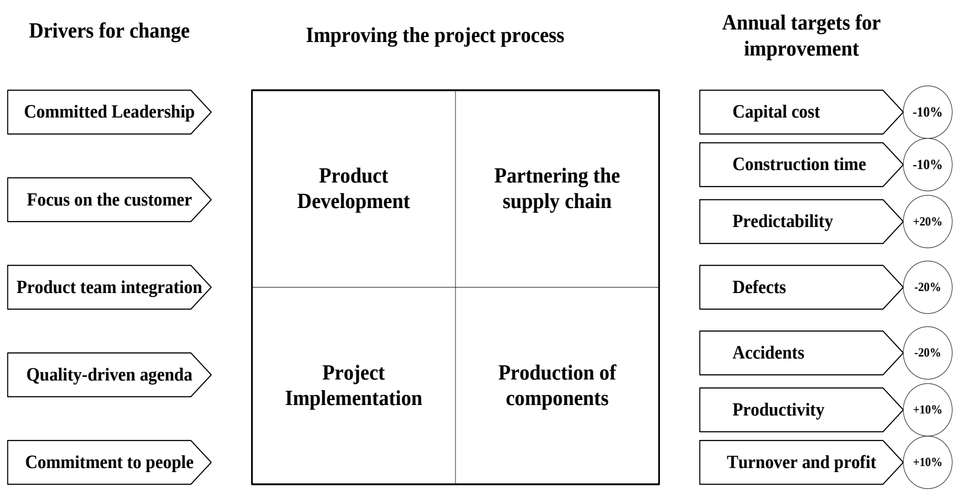



Figure 2.8: The Egan agenda for change (Source: Strategic Forum for Construction (2002))

### 2.3.3 The Revitalising H&S Initiative

Although the UK has a systematic legal framework for construction H&S, construction as well as other industries still account for significant rates of injuries and ill-health cases. In 1999, against the background of worrying H&S statistics in the UK, the then Deputy Prime Minister, John Prescott, announced The Revitalising Health and Safety (RHS) initiative to inject new impetus and re-launch the health and safety agenda, 25 years after the HSWA 1974 (Department of the Environment Transport and the Regions, 2000). Following this, there was public consultation overseen by an Inter-Departmental Steering Group comprising all Government Departments with direct responsibility for aspects of H&S at work. The public consultation involved a spectrum of stakeholders including the Confederation of British Industry, the Trades Union Congress, and the Federation of Small Businesses. From the consultation, The RHS targets were launched. These were to:

- reduce the number of working days lost per 100,000 workers from work-related injury and ill-health by 30% by 2010;
- reduce the incidence rate of fatal and major injury accidents by 10% by 2010;
- reduce the incidence rate of cases of work-related ill-health by 20% by 2010; and
- achieve half the improvement under each target by 2004.

These targets were accompanied by a strategy statement and an action plan to enable their achievement. The strategy statement encompassed: promotion of better working environments; workforce contribution; occupational health; engagement of small firms; motivating employers; self-regulation; partnership on health and safety issues; leadership by Government; education; and designing H&S into processes and products.

Following the launch of the above targets for all industrial sectors, the Construction Industry Advisory Committee (CONIAC) to the Health and Safety Commission (HSC) went a step further to set more ambitious targets for the construction industry which considerably exceeded the above targets set for all industries (Hughes and Ferrett, 2008; HSE, 2009a). These were to:

- reduce the incidence rate of fatalities and major injuries by 40% by 2004/05 and by 66% by 2009/10;
- reduce the incidence rate of cases of work-related ill-health by 20% by 2004/05 and by 50% by 2009/10; and
- reduce the number of working days lost per 100,000 workers from work-related injury and ill-health by 20% by 2004/05 and by 50% by 2009/10.

Following the launch of the Revitalising Health and Safety Initiative an assessment by the HSE Construction Division (2009) (shown by Figure 2.9) indicates that major and fatal injury rates were persistently below the RHS target indicating significant improvement in major injuries and fatal injuries. A general trend of improvement can also be seen from the declining rate of over 3-day injuries.

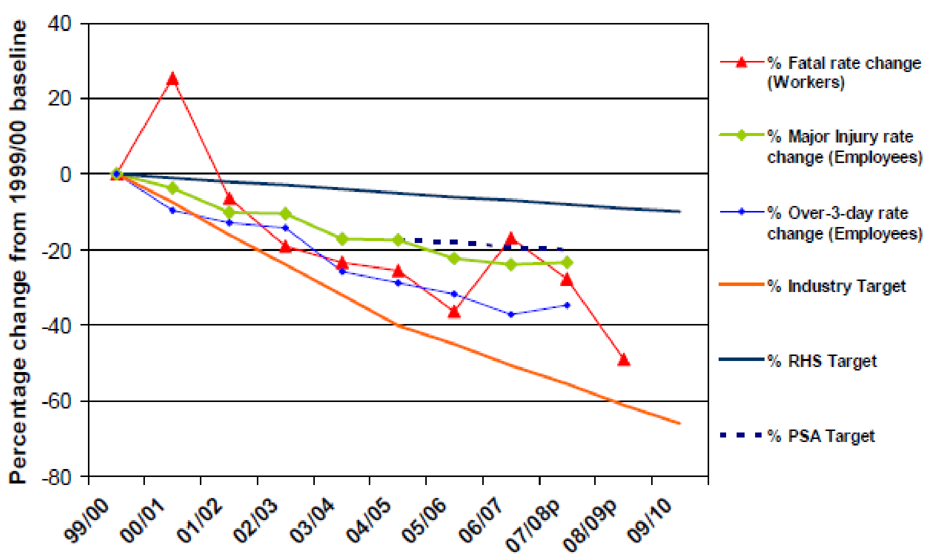



Figure 2.9: Progress against targets: changes in incidence rates (p= provisional) (HSE Construction Division, 2009)

In spite of the general trend of improvement, the assessment shows that major and fatal injury rates persistently exceeded the construction industry target. More recent statistics by the HSE (20011d) also shows that fatal injury rate and major injury rate to employees have reduced by 50% and 40% respectively from 1999/2000 to 2009/2010 (provisional) and thus indicating that the construction industry target (i.e. 66 % reduction by 2009/2010) has not been met. This implies the need for further improvement which is also echoed by industry headlines such as “One Death is Too Many” of the Rita Donaghy Report (Donaghy, 2009) and “Target Zero” (cf. Carrilion, 2010). Efforts to meet the need for H&S improvement can also be seen in the numerous investigations into accident causation witnessed in the construction industry. Such studies are crucial to the H&S improvement agenda as it is by the identification of accident causal factors that effective accident measures can be designed and implemented. As part of highlighting efforts to improve the H&S performance of the industry, it is thus important to accord some attention to accident causation studies.

## 2.4 SUMMARY

The UK construction industry is responsible for the delivery of the nation’s built environment. The output of the industry exceeds £100 billion, and it employs over 2 million people. Clearly, this industry is significant in its size, and more importantly in its contribution to the UK economy. Despite its socio-economic benefits, the industry accounts for a significant proportion of occupational deaths, injuries and ill-health. This state of affairs is associated with significant cost and has triggered considerable efforts towards improving H&S. These include H&S legislation and industry initiatives such as the Revitalising H&S Initiative and the Egan and Latham reports. As improving the H&S situation requires the identification of factors contributing to the occurrence of injuries and illnesses so that effective measures can be developed, over the years other efforts aimed towards contributing to achieving H&S improvement have been witnessed in the form of research into the causes of construction accidents. The next chapter thus reviews studies on construction accident causation.

# CHAPTER 3: CAUSAL FACTORS IN CONSTRUCTION ACCIDENTS AND THE ROLE OF CONSTRUCTION PROJECT FEATURES

## 3.0 INTRODUCTION

In the preceding chapter it was shown that the H&S performance of the UK construction industry is worrying and demands improvement. As part of highlighting the efforts directed towards driving H&S improvement the previous chapter presented the H&S legislation and some past initiatives. Building on this context, this chapter continues to highlight efforts aimed at improving the H&S performance of the construction industry by focusing on construction accident causation studies as the delivery of effective improvement agenda is inevitably tied to the identification of factors responsible for accidents from which deaths, injuries and ill-health emerge. This chapter thus reviews studies on construction accident causation. It points out the accident causal role of CPFs and highlights the scope for further studies. This chapter thus completes the achievement of the first research objective which is to undertake a critical review of the state of H&S in the UK construction industry highlighting the H&S performance, challenges, some improvement efforts and the accident causal influence of CPFs.

## 3.1 CONSTRUCTION ACCIDENT CAUSATION STUDIES

As improving the H&S situation requires the identification of the factors contributing to the occurrence of injuries and illnesses, over the years there have been several accident causation studies to identify the causes of construction accidents (cf. Suraji *et al.*, 2001; Haslam *et al.*, 2005; Brace *et al.*, 2009; Cooke and Lingard, 2011) resulting in the reporting of several factors in construction accidents.

Majority of the research that have explored causal factors in construction accidents in UK have been commissioned by the HSE (cf. Whittington *et al.*, 1992; Suraji *et al.*, 2001; Haslam *et al.*, 2005; Brace *et al.*, 2009). The HSE (1978; 1988) examined fatal accident cases and suggested causes such as failure to ensure safe systems of work, poor maintenance, use of defective materials, and poor supervision and training. Against the historical background of research which tended to focus on the contribution of individual (frontline) workers to accidents, Whittington *et al.*, (1992) explored the link between accidents and management and organisational factors. The study was conducted in support of the thesis that poor management decision-making together with inadequate management controls makes a major contribution to many accidents occurring on construction sites. A mixed method approach involving: analysis of 30 accident cases; interviews with project managers, site managers and safety officers; and a postal survey of 21 companies was adopted. The identified causes of accidents were classified under 3 factors:

- factors relating to headquarter issues (e.g. problems with selection of subcontractors or workforce, inadequate safety training of site management or supervisors, and failure to consider safety implications of building design);
- factors relating to site management issues (e.g. failure to set up safe work, failure to communicate safe system of work, and failure to supervise employees and subcontractors); and
- factors relating to the injured person or his immediate work colleagues (e.g. unsafe act/risk taking behaviour, and miscommunications between operatives on site).

The findings by Whittington *et al.* (1992) focussed on company failures which can trigger individual failures leading to accidents. Although they acknowledged the potential influence by clients in triggering unsafe worker behaviour, their findings did not extend to accident causal factors at the commissioning stage of projects. Whittington *et al.* (1992) developed a model of accident causation which shows a sequence of failures which leads to accidents.

Suraji *et al.* (2001) investigated 500 accident records and reported a number of causes of accidents classed as proximal accident factors. Suraji *et al.* (2001) explained that proximal accident factors are accident factors that lead directly to accident occurrence. Broadly, the proximal factors cover: inappropriate construction planning; inappropriate construction control; inappropriate site condition; inappropriate construction operation; and inappropriate operative actions. The frequency of these factors within the 500 accidents is shown in Table 3.1 and a detailed breakdown of the causes of accidents under the factors is also given by Table 3.2.

Table 3.1: Types of proximal factors

| **Proximal factor** | **Accidents caused by proximal factors (%)** [a] |
|---|---|
| Inappropriate construction planning | 28.8 |
| Inappropriate construction control | 16.60 |
| Inappropriate construction operation | 88.0 |
| Inappropriate site condition | 6.00 |
| Inappropriate operative action | 29.80 |

[a] Multiple involvement of factors leads to sum greater than 100%

Source: Suraji *et al* (2001)

The findings of this study provided partial validation of an accident causation model developed by Suraji *et al.* (2001). In addition to proximal accident factors, the model by Suraji *et al.* (2001) acknowledges that there are underlying accident causes at the commissioning stages of projects which trigger the proximal accident causes. These causes were classed as distal causal factors due to their remoteness to accidents. However, the analysis of the accident record only provided evidence of the proximal causal factors. Suraji *et al.* (2001) hinted that the validation of the underlying causes was being undertaken in a HSE funded research by a research team at Loughborough University. This was the study reported by Haslam *et al.* (2005).

Table 3.2: Details of proximal factors

| **Type of factor** | **Proximal causes** | **Percent of accidents (%)** [a] |
|---|---|---|
| Inappropriate construction planning | Inadequate method statement | 11.40 |
| | Inadequate preparatory training | 8.80 |
| | Inadequate identification and assessment of risk | 8.00 |
| | Inadequate planning of construction work | 3.40 |
| | Inadequate safety plan | 3.00 |
| | Inadequate structural design for temporary support structures | 2.80 |
| Inappropriate construction control | Inadequate supervision of operative work | 6.20 |
| | Inadequate control of systems of work | 4.20 |
| | Inadequate control of the stability of temporary structures | 2.40 |
| | Inadequate control of plant or equipment operation | 2.20 |
| Inappropriate site condition | Unsuitable weather or climatic conditions | 3.00 |
| Inappropriate construction operation | Breach of regulation or code of practice | 54.60 |
| | Defective or unsuitable access/egress | 18.80 |
| | Inadequate safety facilities | 15.40 |
| | Improper construction procedure | 15.00 |
| | Defective equipment or vehicle | 9.80 |
| | Inadequate provision or safety warnings or other precautions | 6.80 |
| | Inadequate working platform, including no guardrails | 6.60 |
| | Untrained or inexperienced workforce | 6.00 |
| | Improper plant or equipment operation | 4.20 |
| | Improper instruction to operatives | 3.60 |
| | Inadequate working tools or instruments | 3.60 |
| | Inadequate temporary structure | 3.40 |
| | Defective services | 3.20 |
| | Unsuitable plant or equipment | 2.60 |
| | Inadequate communication or coordination | 2.20 |
| Inappropriate operative action | Improper or inadequate use of PPE | 6.00 |
| | Failure to follow instructions | 5.20 |
| | Carelessness | 5.00 |
| | Failure to adopt standard procedures | 4.40 |
| | Improper working position | 4.20 |
| | Judgment error, underestimate, overconfidence | 4.00 |
| | Others (undefined) | 2.20 |

[a] Multiple involvement of factors leads to sum greater than 100%

Source: Suraji *et al.* (2001)

In a study of 68 fatal accidents by Bomel Limited (2003) cited in HSE Construction Division (2009), accident causal factors including: poor situational awareness; work environment failings; poor individual competence; deficiencies in planning; deficiencies in standards of tool, equipment and PPE; deficiencies in management and supervision; and safety culture were identified in at least approximately 60% (i.e. over half) of the cases. Poor situational awareness was the most recurrent (i.e. in 80% of the cases). The causal factors were classified under three broad factors:

- direct level factors (i.e. the immediate workplace influencing factors that have a bearing on the human and technical conditions which can lead to unsafe acts and/or technical failures that are responsible for the accident);
- organisational level factors (i.e. the underlying organisational influencing factors that affect the human and technical conditions of the working environment and therefore shape the occurrence of human/technical failures); and
- policy level factors (i.e. policy and corporate level influencing factors that determine the organisational processes).

In a subsequent study, Bomel Limited *et al.* (2006) examined 27 and 63 fatal accidents in Scotland and in the rest of Great Britain respectively. The findings were generally similar to those reported in Bomel Limited (2003) cited in HSE Construction Division (2009). Again the causal factors were classified under direct, organisational and policy level factors. This classification of accident factors adopts the systems approach to understanding causation which concerns the underlying conditions responsible for immediate causes (Bomel Limited *et al.*, 2006). Bomel Limited *et al.* (2006) noted difficulty in identifying policy level factors which are remote to accidents. Like the study by Whittington *et al.* (1992) and Suraji *et al.* (2001), this study did not identify causal factors which are upstream of the project procurement process due to limitations in accident records and difficulty in identifying such causal factors given their remoteness to accident events (cf. Suraji *et al.*, 2001; Haslam *et al.*, 2005; Bomel Limited *et al.*, 2006).

The study by Haslam *et al.* (2005) presented a major advancement in construction accident causation knowledge to the extent that it made up for the limitation of the previous studies by identifying underlying causes of accidents which go beyond the construction site. Haslam *et al.* (2005) used both qualitative and quantitative approaches involving focus group interviews followed by analysis of 100 accidents. The identified causes of accidents were classified under three hierarchies of causal factors:

- immediate accident circumstances (i.e. the interaction between the work team, workplace, equipment and materials e.g. suitability of materials, suitability of equipment, usability of materials, and usability of equipment);
- shaping factors (i.e. proximal influences which shape the immediate accident circumstance e.g. site conditions, site layout/space, work scheduling, and housekeeping); and
- originating influences (i.e. the high level determinants of the nature, extent and existence of immediate causes of accidents e.g. permanent works design, project management and risk management).

A breakdown of the factors in the 100 accidents is shown by Table 3.3. From the findings, Haslam *et al.* (2005) developed an accident causation model illustrating the causal relationship between the 3 hierarchies of accident factors.

Table 3.3: Summary of factors involved in the 100 accidents

| **Category** | **Factors involved** | **Percentage of accidents (%)** [a] |
|---|---|---|
| Worker and work team | Worker actions/behaviour | 49 |
| | Worker capabilities (including knowledge/skills) | 42 |
| | Communication | 7 |
| | Immediate supervision | 13 |
| | Worker health/fatigue | 5 |
| Workplace | Site conditions (excluding equipment, materials, weather) | 11 |
| | Working environment (lighting/noise/hot/cold/wet) | 9 |
| | Site layout/space | 15 |
| | Work scheduling | 11 |
| | Housekeeping | 19 |
| Materials | Suitability of materials | 12 |
| | Usability of materials | 8 |
| | Condition of materials | 13 |
| Equipment | Suitability of equipment | 44 |
| | Usability of equipment | 19 |
| | Condition of equipment | 12 |
| Originating influences | Permanent works design | 27 |
| | Project management | 24 |
| | Construction processes | 12 |
| | Safety culture | 15 |
| | Risk management | 84 |

[a] Multiple involvement of factors leads to sum greater than 100%

Source: Haslam *et al.* (2005)

Using a qualitative approach (involving expert consultation (based on interviews) and stakeholder reviews (involving focus groups), the following causes were presented under three themes (i.e. macro, messo, and micro factors):

- Macro: immature corporate systems; inappropriate enforcement; lack of proper accident data; lack of leadership from government as a key client; and lack of influence of trades unions.
- Messo: immature project systems and processes; inappropriate procurement and supply chain arrangements; lack of understanding and engagement by some of the design community; lack of proper accident investigation/data, and lack of organisational learning.
- Micro: lack of individual competency and understanding of workers and supervisors; ineffectiveness or lack of training and certification of competence; poor behaviour;

cost; poor equipment or misuse of equipment (including PPE); site hazards; poor employment practices; itinerant workforce; and inadequate management of and provision for vulnerable workers.

Brace *et al.* (2009) mentioned that the themes can be considered as potential defensive plates against accidents. It is further explained that when active or latent failures create holes in the defensive plates, accidents can occur, with the 'chance' element being represented by the chance of the holes in the various plates lining up to provide an opportunity for 'accident trajectory', as shown in Figure 3.1 (Brace *et al.*, 2009).

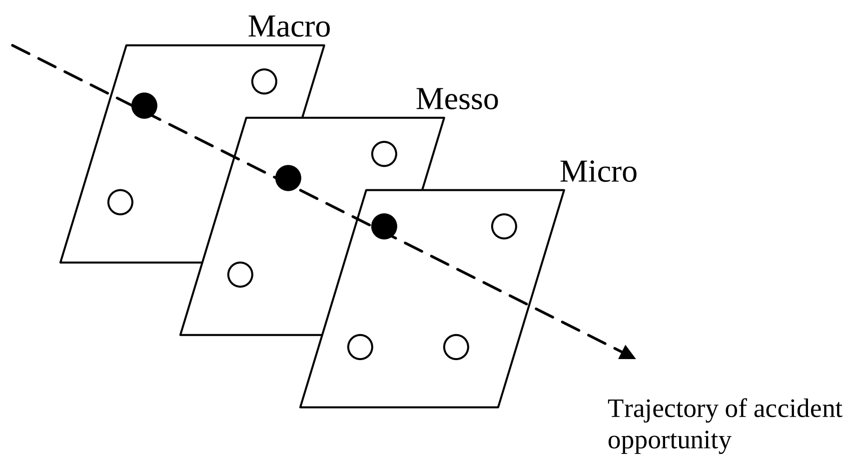



Figure 3.1: Thematic summary of underlying causes of fatal accidents (Brace *et al.*, 2009)

In reviewing construction accident causation literature, studies outside the UK context are also worthy of consideration and these are summarised by Table 3.4 below. As shown by Table 3.4, similar to the UK studies, the reported causes of accidents have in the main focused on: the worker; site conditions and activities; and the management of H&S by the construction organisation (i.e. contractor) with few studies reporting underlying causes which extend to the commissioning stages of a project (cf. Behm, 2005).

Table 3.4: Construction accident causation studies outside the UK context

| Author | Location of study | Method of study | Causes of accident /findings | Focus of causal factors |
|---|---|---|---|---|
| Occupational Safety and Health Administration (OSHA) (1990) | USA | Analysis of construction fatalities. | 33% of the investigated fatalities are due to falls, 22% are as a result of the victim being struck-by an object, 18% are caught-in between accidents, 17% are due to electrocutions, and 10% are caused by other conditions (e.g. toxic gases, drowning, and fire). | Proximate causes which do not extend upstream of project procurement. |
| Hinze (1996) | USA | Desk study. | Proposed that accidents are caused by worker distraction either due to physical hazards or mental diversion. | Proximate causes which do not extend upstream of project procurement. |
| McVittie *et al.* (1997) | Canada | Assessment of the influence of firm size on lost-time injury rates by reviewing records relating to injuries, man hours, payroll and firm size. | It was found that injury frequency increased consistently as firm size decreased. Factors responsible for this effect were suggested to include better organisation, greater awareness of health and safety, higher rates of unionisation and better training among larger firms. | Proximate causes which do not extend upstream of project procurement. |
| Lam and Rowlinson (1997) | Hong Kong | Analysis of government statistics. | Causes of accident are: difficulties in adaptation for new immigrant workers, employment of unskilled workers, overtime work, lack of leadership from top management, poor working attitudes, shortage of factory inspectors, low penalties for breaches of the safety law, inadequate safety education courses, inadequate authority of the Labour Department, and poor site supervision. | Proximate causes as well as underlying causes which extend upstream of project procurement. |
| Hinze *et al.* (1998) | USA | Analysis of 1,082 accidents. | 34% of the investigated fatalities are due to falls, 18% are as a result of the victim being struck-by an object, 15% are caught-in between accidents, 20% are due to electrocutions, and 13% are caused by other conditions (e.g. toxic gases, drowning, and fire). | Proximate causes which do not extend upstream of project procurement. |
| Kartam and Bouz (1998) | Kuwait | Examined 148 accidents. | The causes of the accidents in the sample are: worker turnover and false acts; inadequate safety procedures; improper cleaning and unusable materials; and destiny. | Proximate causes which do not extend upstream of project procurement. |
| Gherardi *et al.* (1998) | Italy | Interviewing of construction site engineers and site managers. | From the engineers' perspective, an underlying cause of accident is human error whereas the site managers consider underlying causes of accidents to be difficulties in site coordination, | Proximate causes which do not extend upstream of project |

| Author | Location of study | Method of study | Causes of accident /findings | Focus of causal factors |
|---|---|---|---|---|
| | | | lack of respect for safety norms, and lack of organisational control. | procurement. |
| Abdelhamid and Everett (2000) | USA | Desk study. | Proposed three root causes: (1) failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started; (2) deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and (3) deciding to act unsafely regardless of initial conditions of the work environment. | Proximate causes which do not extend upstream of project procurement. |
| Egawa and Nakamura (2000) | Japan | Examined accident reports. | Identified communication errors between workers to be responsible for a large number of accidents. | Proximate causes which do not extend upstream of project procurement. |
| Lubega *et al*. (2000) | Uganda | A case study involving interviews, and a questionnaire survey. | Reported causes of accidents include: lack of awareness of safety regulations; lack of enforcement of safety regulations; poor regard for safety by people involved in construction projects; engaging incompetent personnel; non-vibrant professionalism; mechanical failure of construction machinery/equipment; physical and emotional stress; and chemical impairment. | Proximate causes as well as underlying causes which extend upstream of project procurement. |
| Toole (2002) | USA | Desk study. | Proposed that root causes of accidents are: lack of proper training; deficient enforcement of safety by supervisors; safety equipment not provided; unsafe methods or sequencing; unsafe site conditions; not using provided safety equipment; poor attitude towards safety; and isolated, sudden deviation from prescribed behaviour. | Proximate causes which do not extend upstream of project procurement. |
| Arboleda and Abraham (2004) | USA | Examined 296 fatal trenching accidents. | Reported that root causes of accidents are: lack of proper training; deficient enforcement of safety by supervisors; safety equipment not provided; unsafe methods or sequencing; unsafe site conditions; not using provided safety equipment; poor attitude towards safety; and isolated, sudden deviation from prescribed behaviour. | Proximate causes which do not extend upstream of project procurement. |
| Behm (2005) | USA | Investigated the link between 230 construction fatal accidents and the design for safety | Found that 42% of the fatal accidents are associated with design factors. | Underlying causes which extend upstream of project procurement. |

| **Author** | **Location of study** | **Method of study** | **Causes of accident /findings** | **Focus of causal factors** |
|---|---|---|---|---|
| | | concept. | | |
| Hinze *et al*. (2005) | USA | Examined 743 'struck by' accident cases. | Causes of accidents include misjudgement of hazardous situation; malfunction of procedure for securing operation or warning of hazardous situation; and inappropriate procedure for handling materials for task. | Proximate causes which do not extend upstream of project procurement. |
| Chi *et al*. (2005) | Taiwan | Examined 621 occupational fatal accidents. | Causes of accidents include: lack of complying scaffold/platform; unguarded openings; and lack of fixed barrier. | Proximate causes which do not extend upstream of project procurement. |
| Choudhry and Fang (2008) | Hong Kong | Interviews with seven operatives, two site engineers, two safety managers and one project manager. | Accident causes are inadequate supervision, inadequate training, inadequate planning, employee error, and accident beyond ones control. | Proximate causes which do not extend upstream of project procurement. |
| Hamid *et al.* (2008) | Malaysia | Analysis of 128 accident cases and a questionnaire survey. | Causes of accidents are unsafe equipment , job site conditions, unique nature of industry (e.g. work at height, transient workforce, high energy required, limitation of working area), unsafe method, human element (e.g. negligence), and management (e.g. poor inspection). | Proximate causes which do not extend upstream of project procurement. |
| Ling *et al*. (2009) | Singapore | Examined 40 fatal construction accidents. | Causes of accidents are rushing to complete work, working without using personal protective equipment, lack of safety awareness, personal negligence, carelessness, and lack of supervision. | Proximate causes which do not extend upstream of project procurement. |
| Cooke and Lingard (2011) | Australia | Analysis 258 construction work-related deaths based on the ConCA model by Haslam *et al*. (2005). | Of the 258 cases, no clear causes were identified for 66 cases, and immediate causes (e.g. local hazards, layout, equipment usability, material usability) were identified in the remaining 192 cases. Of the 192 cases for which immediate causes were identified, inter-mediate causes/shaping factors (e.g. supervision, site constraints, work scheduling, and housekeeping) were identified in 121 cases out of which underlying causes (e.g. client requirement, permanent works design and project management) were also identified in 87 cases. | Proximate causes as well as underlying causes which extend upstream of project procurement. |

The above review clearly demonstrates that considerable efforts have been directed towards studying construction accidents. It is important to acknowledge that these studies appear to make worthwhile contributions as part of efforts aimed at improving H&S as their findings provide knowledge for developing accident prevention strategies. Also the review indicates the variety of methods/approaches that have been used in studying construction accidents and this can be useful in developing strategies for delivering further research in this area.

From the review it is also evident that most construction accident causation studies have focussed on site-based factors or factors relating to the H&S management of the contractor with a few examining underlying causal factors which are upstream of the procurement process. Brace *et al.* (2009) similarly made this observation. Studies by Haslam *et al.* (2005), and Brace *et al.* (2009) are among the few studies that have examined underlying accident causal factors. Even among studies which sought to report root causes, the causes reported by some of those studies have been noted as rather being proximate causes (cf. Abdelhamid and Everett, 2000; Gibb *et al.*, 2000; Suraji and Duff, 2000) as they relate to the worker and site management which are subject to higher level influences which extend to the commissioning stages of project. For instance, following the publication by Abdelhamid and Everett (2000) regarding root causes, Suraji and Duff (2000) and Gibb *et al.* (2000) expressed that the labelling of the factors reported by Abdelhamid and Everett (2000) as root causes is misleading as the factors relate to worker error and the work environment which are subject to the influence of remote causal factors which extend beyond the construction phase.

The limited focus on underlying causes of accident has consequences for H&S as it has been established that in order to prevent accidents on a long-term and sustainable basis there is the need to pay attention to root accident causal factors which are upstream of the project procurement process (Haslam *et al.*, 2005; Brace *et al.*, 2009). The need to focus on underlying causal factors is also reinforced by the fact that the pre-construction stage from which they emanate offers project participants the greatest opportunity to influence H&S on projects (Szymberski, 1997; Brabazon *et al.*, 2000).

Despite the established significance of underlying/root accident causal factors to H&S, not much by way of research has focussed on the accident causal role of construction project features (CPFs) which emanate from the pre-construction stage of projects. In most cases only passing references have been made to the accident causal role of CPFs despite the considerable H&S reports and studies persistently linking CPFs such as nature of project, method of construction, project duration and procurement system to accidents and their tragic outcomes such as injuries, deaths and illnesses (cf. Egbu, 1999; Hide *et al.*, 2003; Hughes and Ferrett, 2008; HSE, 2009a). Even among the studies which have examined underlying causes of accidents no specific focus has been accorded to the accident causal phenomenon of CPFs and this could be due to the inherent difficulties in examining underlying causes whose influence tends to be subtle and could thus go unnoticed (cf. Haslam *et al.*, 2005; Bomel Limited *et al.*, 2006; Cooke and Lingard, 2011). Haslam *et al.* (2005) for instance reported that it is difficult to trace causation from accidents to root causes.

Given the paucity of research focus that has been given to the accident causal influence of CPFs despite the established significance of root causes to H&S, it is worth according this causal phenomenon some research attention to enable the attainment of further insight towards addressing it within the wider context of contributing to efforts towards achieving sustained H&S improvement. The following sections critically examines the influence of CPFs in accident occurrence to accentuate the inherent gaps that need filling and then make a case for bridging those gaps.

## 3.2 THE ACCIDENT CAUSAL INFLUENCE OF CPFs

CPFs such as the nature of project, method of construction, site restriction, project duration, procurement system, design complexity, level of construction, and subcontracting have been noted to influence accident occurrence in construction (cf. Horbury and Hope, 1999; McKay *et al.*, 2002; Hide *et al.*, 2003; Gambatese *et al.*, 2008; HSE, 2009a). These are organisational, operational, and physical attributes that characterise construction projects, and to a large extent they emanate from pre-construction decisions by the client (i.e. client's brief), project management team and design team. CPFs are thus among the root causal influences in construction accidents which manifest at the commissioning stages of projects. The accident causal influence of CPFs is revealed by the following critique of construction H&S literature.

### 3.2.1 Nature of Project

The nature of project (i.e. new work, refurbishment and demolition) is usually determined by the client's brief. The UK Office for National Statistics (ONS) (2008; 2009) indicates that compared to new work, repair and refurbishment work constitute a fairly consistent proportion of approximately 45% of the industry's output. The UK HSE Construction Intelligence Report (HSE, 2009a), however demonstrates that refurbishment and repair work constitutes a fairly consistent proportion of fatal accidents at around 50%. Refurbishment and repair work therefore accounts for a disproportionate percentage of fatal accidents. This trend is attributable to the fact that, the hazards during refurbishment are more uncertain and hence difficult to observe and evaluate than the hazards on new works (cf. Egbu, 1999; Anumba *et al.*, 2006). Like refurbishment work, demolition work shares similar attributes and is also a hazardous operation responsible for accidents (Hughes and Ferrett, 2008). Hazardous incidents and substances such as falling debris, pre-mature collapse of element/structures, dust and fumes, asbestos, noise and vibration, and electric shock are common in demolition and refurbishment work (Anumba *et al.*, 2006; Hughes and Ferrett, 2008), and given that these tend to be *uncertain*, it is only consequential that refurbishment work and demolition work are more dangerous than new work (Anumba *et al.*, 2004; Anumba *et al.*, 2006).

### 3.2.2 Method of Construction

Studies have pointed to the contribution of method of construction (as determined by the designer) to accident causation (cf. Gibb, 1999; 2001; McKay *et al.*, 2002; Hide *et al.*, 2003; Wright *et al.*, 2003). This can be related to the extent of *manual handling* which is involved in one-third of all construction accidents in the UK (HSE, 2009a). Perttula *et al.* (2003) in Finland similarly attributed manual handling to a third of the accidents in their study. The conventional on-site (i.e. traditional in-situ) method, compared to pre-assembly (off-site fabrication), involves extensive manual handling and therefore introduces more manual handling hazards and thus implying a causal link to manual handling injuries. Conventional on-site construction is also noted for its greater association with housekeeping problems which cause accidents (Hide *et al.*, 2003; Wright *et al.*, 2003). Gibb (2001) noted that because pre-assembly brought the construction site into the factory where the environment is more controllable, safety, productivity and quality could be improved. The Strategic Forum for Construction (2002), McKay *et al.* (2002), Hide *et al.* (2003), Wright *et al.* (2003), and McKay (2010) have also underscored the H&S benefits of using pre-assembly construction. Despite the H&S benefits of pre-assembly construction, it also has accident implications which can be related to its reliance on the use of mechanical means of handling (Hughes and Ferrett, 2008).

### 3.2.3 Site Restriction

Compared to an unrestricted site, a restricted site (i.e. a site where the floor area not covered by the structure to be constructed is much smaller than the floor area to be covered by the structure) implies insufficient space on site, and hence limited or congested space for the operatives, plants, machines and equipment, and storage on site (cf. Hide *et al.*, 2003). Restricted sites influence accidents as a result of the inherent *site congestion* which has been a persistent cause of accidents on site (Brabazon *et al.*, 2000; Hide *et al.*, 2003; Brace *et al.*, 2009). Congested site conditions implies insufficient working space, constricted room for vehicle manoeuvrability and difficult access to drop-off points, possibly resulting in the need for double handling of materials, all of which have safety implications (Hide *et al.*, 2003). Congested site conditions could also influence accidents involving workers being struck by moving vehicles or objects which are also among the common kinds of fatal accidents in construction (HSE, 2009a).

### 3.2.4 Project Duration

During construction, it is possible that the anticipated/targeted construction duration set by the project planners may eventually not be exactly the actual duration spent as there could be time over-runs or early completion. However, this planned duration, has the potential to influence accident occurrence. A constrained duration set by the client or the project management team implies *time-pressure* at the construction phase with subsequent problems such as trade overlap, crowded work space, reduced attention to detail, and the prioritising of production over safety all of which influence accident occurrence (Mayhew *et al.*, 1997; Hide *et al.*, 2003; Brace *et al.*, 2009).

### 3.2.5 Design Complexity

The influence of design in accident causation has been echoed throughout the construction industry (cf. Brabazon *et al.*, 2000; Hide *et al.*, 2003; Wright *et al.*, 2003; Habilis Ltd, 2004; Donaghy, 2009), hence the existence of the CDM 2007 in the UK. The findings of Hide *et al.* (2003) indicated that an increased desire for aesthetic qualities inhibit *the ease of building* which in itself induces safety hazards. As part of the research informing the Donaghy Report (Donaghy, 2009), Brace *et al.* (2009), again mentioned poor design for buildability as a causal factor in construction fatalities. Designs that are complex (*having intricate aesthetic qualities*) therefore have a greater potential to influence accident occurrence as such designs inhibit buildability (Hide *et al.*, 2003).

### 3.2.6 Subcontracting

Several studies within the construction industry have identified subcontracting as a causal factor in construction accidents. In countries such as Spain, Malaysia, Philippines, Poland, China, and Australia, subcontracting has been associated with adverse H&S outcomes in the construction industry (cf. Byrne and van der Meer, 2001; ILO, 2001; Wong and So, 2002; Yung, 2009). Similarly in the UK, the accident causal influence of subcontracting has been reported over the years (cf. Mayhew and Quinlan, 1997; Horbury and Hope, 1999; Hide *et al.*, 2003; Ankrah, 2007; Donaghy, 2009; Manu *et al.*, 2011a). Subcontracting could emanate from the pre-construction phase (through decisions by the project planners and client) and/or during the construction phase (through decisions by a main contractor/contractor and client/client representative). Subcontracting inherently *fragments the workforce* thus making it difficult to manage H&S on site and hence leading to accidents (Mayhew *et al.*, 1997; Hide *et al.*, 2003).

### 3.2.7 Procurement System

The construction industry is complex covering a large number of players (cf. ONS, 2011). In view of this, Brabazon *et al.* (2000) for instance reported that there are organisational obstacles within the UK construction industry which impede H&S improvement. Interaction in the supply chain is often divisive rather than supportive and this impedes H&S improvement (Brabazon *et al.*, 2000). Partnering has for instance been mentioned to have the potential to enhance site safety management (cf. Matthews and Rowlinson, 1999). Brabazon *et al.* (2000) similarly indicated that partnering is perceived as being able to enhance H&S improvement as it enables the building of more collaborative working relationships and hence provides greater opportunities for discussion, hazard identification and problem solving at the early stage of the project.

Another procurement arrangement which is perceived as being able to enhance H&S management is design and build (cf. Hide *et al.*, 2003). Hide *et al.* (2003) reported that design and build procurement is perceived as enabling H&S improvement because the contractual arrangements place the responsibility for both design and construction within a single project team, leading to shared goals, improved communication, and a better environment for new ideas to flourish. These procurement arrangements promote team integration, which manifests in enhanced collaboration among project participants, an important ingredient for project success (Egan, 1998; Strategic Forum for Construction, 2002; Baiden, 2006). Unlike partnering and design and build procurement, a procurement arrangement that has been mentioned to have adverse H&S implications is management contracting (Horbury and Hope, 1999). Management contracting is considered more problematic than the traditional mode of procurement when addressing the maintenance of good H&S (Horbury and Hope, 1999). Evidently these latter procurement arrangements are associated with greater fragmentation of project participants, implying less collaborative working which impedes effective management of H&S on project.

### 3.2.8 Level of Construction

Multi-level/high-level construction greatly involves *working at height* which accounts for falls from height. This increases the risk of falls from height which accounted for about 50% of fatal injuries in the UK from 1996/97 to 2007/08 (HSE, 2009a). Multi-level/high-level construction thus contributes to accident causation. Research by Chua and Goh (2005) in Singapore also revealed that underground construction has a higher rate of incidents than above-ground construction. Although Chua and Goh (2005) did not delve deeply into the possible reasons for the higher rate of incidents associated with underground construction, it is well known that underground construction involves *working in confined space* which accounts for adverse H&S outcomes (cf. Hughes and Ferrett, 2008) hence the existence of the Confined Spaces Regulations 1997 in the UK.

### 3.2.9 Summary of the Accident Causal Influence of CPFs

From the above review, it is evident that the accident causal influence of CPFs is undoubtedly existent and has severe ramifications. This underscores the need to address root accident causal factors to ensure sustained improvement in H&S (Haslam *et al.*, 2005). A summary of the review as shown by Table 3.5 also demonstrates clearly that the accident causal influence of CPFs has appreciably and persistently been reported.

Despite the appreciable and persistent reporting of the accident causal influence of CPFs, detailed insight about this causal phenomenon which is essential for redressing it still remains elusive. There is lack of clarity within the extant H&S literature regarding the degree of potential of CPFs to influence accident occurrence (i.e. their potential to cause accident), their degree of associated H&S risks (i.e. the likelihood of accident occurrence due to CPFs) and the mechanism by which they influence accident occurrence.

Table 3.5: Literature sources highlighting the accident causal influence of CPFs

| **Literature Source** / **CPFs** | Mayhew and Quinlan (1997) | Egbu (1999) | Horbury and Hope (1999) | Gibb (1999, 2001) | Brabazon *et al.* (2000) | McKay *et al.* (2002) | Strategic Forum for Construction (2002) | Wright *et al.* (2003) | Perttula *et al.* (2003) | Hide *et al.* (2003) | Anumba *et al.* (2004) | Chua and Goh (2005) | Anumba *et al.* (2006) | Ankrah (2007) | Hughes and Ferrett (2008) | Brace *et al.* (2009) | HSE (2009a) | Manu *et al.* (2011a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nature of Project | | ✓ | | | | | | | | | ✓ | | ✓ | | ✓ | | ✓ | |
| Method of Construction | | | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Site Restriction | | | | | ✓ | | | | | ✓ | | | | | | ✓ | | |
| Project Duration | ✓ | | | | ✓ | | | | | ✓ | | | | | | ✓ | | |
| Procurement System | | | ✓ | | ✓ | | | | | ✓ | | | | | | | | |
| Design Complexity | | | | | ✓ | | | | | ✓ | | | | | | ✓ | | |
| Level of Construction | | | | | | | | | | | | ✓ | | | ✓ | | ✓ | |
| Subcontracting | ✓ | | ✓ | | | | | | | ✓ | | | | ✓ | | ✓ | | ✓ |

Although the above review points that CPFs have varying degree of potential to influence accident occurrence, the H&S literature does not offer any detailed assessment of this. Previous studies are limited to providing only a comparative assessment as summarised in Table 3.6 below. As shown by Table 3.6, the insight literature provides is thus simplistic in that it only indicates that comparatively a particular CPF has greater or lesser potential to influence accident occurrence than another without providing a measure/degree of their individual potential to influence accident occurrence.

Table 3.6: Potential of CPFs to influence accident occurrence

| Construction Project Features | **Degree of Potential of CPFs to influence accident occurrence**<br>Lesser → Greater |
|---|---|
| Nature of Project (Egbu, 1999; Anumba *et al.*, 2006) | New work → Refurbishment<br>Demolition |
| Method of Construction (Gibb, 1999, 2001; McKay *et al.*, 2002; Wright *et al.*, 2003) | Pre-assembly construction → Conventional construction |
| Site restriction (Hide *et al.*, 2003; Brace *et al.*, 2009) | Unrestricted site → Restricted site |
| Project Duration (Brabazon *et al.*, 2000; Hide *et al.*, 2003; Brace *et al.*, 2009) | Unconstrained duration → Constrained duration |
| Procurement system (Horbury and Hope, 1999; Matthews and Rowlinson, 1999; Brabazon *et al.*, 2000; Hide *et al.*, 2003) | Design and Build → Traditional → Management contracting<br>Partnering |
| Design Complexity (Hide *et al.*, 2003; Brace *et al.*, 2009) | Simple design (Simple aesthetic qualities) → Complex design (Intricate aesthetic qualities) |
| Level of Construction (Hughes and Ferrett, 2008; HSE, 2009a) | Low-level construction → High-level construction<br>Underground construction |
| Subcontracting (Mayhew and Quinlan, 1997; Hide *et al.*, 2003; Ankrah, 2007; Manu *et al.*, 2011a) | Single-layer subcontracting → Multi-layer subcontracting |

To clarify this point, it is more insightful knowing the individual degree of harmfulness of two substances than just knowing that one substance is more harmful than the other, and this is because the substance with a lesser degree of harmfulness could still pose great danger despite it comparatively having less harmfulness. Conversely the substance with the comparatively greater harmfulness may not pose any danger as its actual measure of harmfulness may not be dire.

Apart from this limitation, the comparative assessment provided in literature is confined to CPFs of the same kind (e.g. comparing pre-assembly construction to traditional method of construction, and comparing new work to refurbishment) and as such it does not give a holistic view of the degree of potential of CPFs to influence accident occurrence. This limitation is also replicated in the H&S literature in terms of the H&S risk evaluation associated with CPFs. For example pre-assembly construction is considered as having lesser H&S risk than traditional method of construction (McKay *et al.*, 2002) and new work is considered as having lesser risk than refurbishment (Anumba *et al.*, 2006). Unlike the comparative assessment of the degree of potential of CPFs to influence accident occurrence, the comparative H&S risk evaluation of CPFs given in literature is even limited to these mentioned CPFs (i.e. method of construction and nature of project).

Aside the above limitations in the extant literature, another aspect of the accident causal phenomenon of CPFs that requires clarity is the mechanism by which CPFs influence accident occurrence. Although there are several accident causation models in the H&S literature which attempt to explain how accidents occur, these models usually provide a generic view of how accidents occur (Suraji, 2001) and often from a particular stand point (e.g. human errors models (cf. Hinze, 1996)). Again, with the exception of a few causation models (cf. Haslam *et al.*, 2005), the models have also often focused on immediate/proximate causes of accidents (cf. Hinze, 1996; Abdelhamid and Everett, 2000). The models therefore do not specifically address the accident causal phenomenon of CPFs. Nonetheless, they may be helpful in developing some framework for a further empirical investigation into how CPFs influence accident occurrence.

Clearly, the above limitations in the extant H&S literature regarding the accident causal influence of CPFs constitute knowledge gaps which warrant investigation as such information is crucial in devising and implementing effective accident prevention measures (cf. Suraji *et al.*, 2001; Haslam *et al.*, 2005; British Standard Institute, 2008).

## 3.3 TOWARDS INTERROGATING THE ACCIDENT CAUSAL INFLUENCE OF CPFs

The above CPFs emanate from decision-making at the pre-construction stage of project procurement, where project participants have an enormous opportunity to influence H&S on projects (Szymberski, 1997; Brabazon *et al.*, 2000). Szymberski (1997) illustrated this by his time-safety influence curve (shown by Figure 3.2) which shows that safety can be influenced to the greatest extent in the early phases of projects.

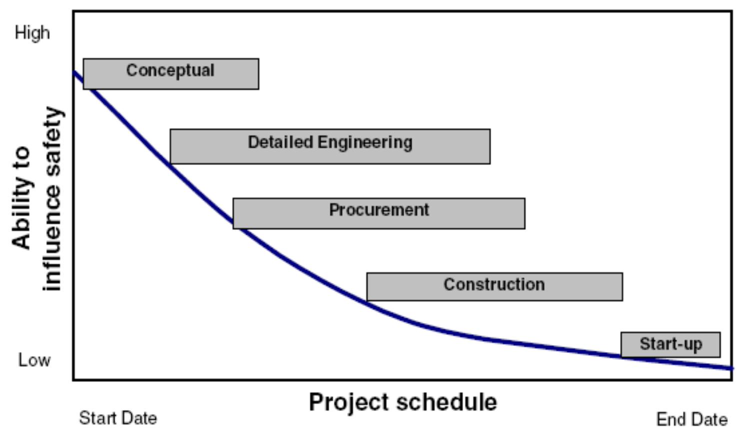



Figure 3.2: Time/safety influence curve (Szymberski, 1997)

Szymberski (1997) indicated that the ideal situation is for construction worker safety to be a prime consideration of the project planners and designers at the conceptual and preliminary design phases in project procurement. Although Szymberski's (1997) time-safety influence curve is in some respect woolly as to the precise nature of the curve, it helps convey in a powerful manner the general acceptance within the industry that the pre-construction stage of project delivery is the best stage to influence H&S on projects (cf. Strategic Forum for Construction, 2002; Office of Government Commerce, 2004; HSE, 2007b; HSE Construction Division, 2009). In this regard Sir John Egan (Strategic Forum for Construction, 2002) for instance commented that;

*"**Pre-planned**, well designed projects, where inherently safe processes have been **chosen**, which are carried out by companies known to be competent, with trained work forces, will be **safe**: they will also be good, predictable projects".*

With the intent of further buttressing the significance of pre-construction H&S planning, it is worthwhile to note that pre-construction planning in general has been mentioned as having a similar influence on cost. Macmillan *et al.* (2001) highlighted that decisions taken at the conceptual design stage of a building project can significantly reduce costs and increase client satisfaction. This is corroborated by Bartolo (2002) who indicated that it is critical to make the correct strategic decisions in the early stages, as it becomes increasingly expensive and unrealistic to make any significant changes as design progresses. Ashworth (2004) gives a graphical illustration of this (as shown in Figure 3.3) which is similar to Szymberski's time-safety influence curve.

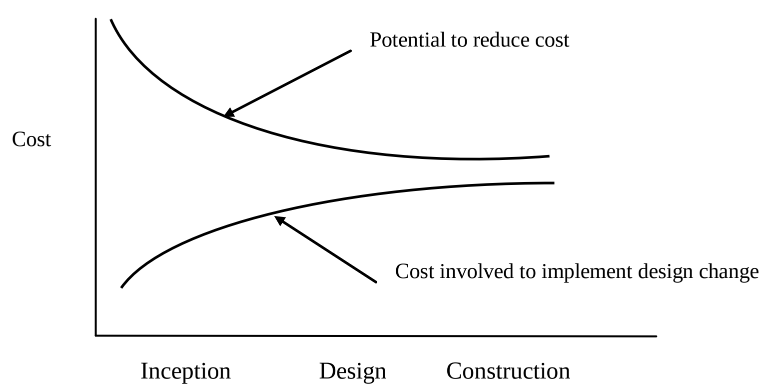



Figure 3.3: Chart illustrating a declining influence on cost along the stages of project procurement (Ashworth, 2004)

It is thus important for project participants involved at the pre-construction stage to be equipped with detailed insight into the accident causal influence of CPFs, in particular, how CPFs influence accident occurrence, their degree of inherent potential to cause accidents and their associated H&S risk. Pre-construction project participants who determine CPFs (through the project brief and their decisions i.e. client, design team and project management team) would by this insight be able to take into consideration the H&S risk implications of CPFs when making such decisions. As project participants have to prioritise in their allocation of resources for controlling risks on projects, the insight of the H&S risk associated with CPFs would again be useful to project participants in informing their prioritising of measures for controlling risk posed by CPFs.

It is acknowledged that pre-construction project participants are often faced with certain constraints which also influence their decisions/choices (cf. Suraji *et al*., 2001). These constraints could be due to the client's requirements, the business/economic environment, or certain implications that may accompany the choice of a particular CPF (e.g. the cost certainty associated with a procurement system, the cost implications of a method of construction, and the economic benefit of subcontracting) (cf. Suraji *et al*., 2001; Wright *et al.*, 2003; Haslam, *et al.*, 2005; Crosthwaite, 2007; Chiang, 2009). For instance, in their study on H&S in public sector construction procurement in the UK, Crosthwaite (2007) reported that the need for cost certainty and time certainty receives greater consideration than the requirement to manage H&S risk when selecting a procurement method. This means that the client, design team and project management team may be constrained by some factors to choose CPFs associated with greater risk despite the H&S implications. Such situations typify trade-offs that transpire in decision-making, and any potentially adverse H&S impacts (resulting from such trade-offs) could be addressed with the help of the insight into how CPFs influence accident occurrence. Understanding how CPFs influence accident occurrence would imply the design team and project management team being able to devise risk control measures in the form of design and project management solutions.

When decisions regarding CPFs have been made and subsequently passed on to the construction team for execution, the construction team could similarly benefit from an awareness of the H&S risk associated with CPFs and the mechanism by which they influence accident occurrence, in terms of devising, prioritising and implementing risk controls to manage the accident causal influence of CPFs.

Against this background, it is evident that an interrogation of the accident causal influence of CPFs is necessary and will be a worthwhile contribution to the wider efforts towards improving construction H&S in particular from the perspective of addressing underlying accident influences through effective pre-construction H&S planning.

## 3.4 SUMMARY

Remedying the poor H&S performance of the construction industry requires detailed understanding of construction accident causation. To this end a considerable number of studies have been undertaken examining the causes of construction accidents. Although some of such studies have stressed the need to pay attention to root causes of construction accidents which manifest at the commissioning stages of projects in order to ensure sustained improvement in H&S, this has generally not been the case. Majority of the construction accident causation studies have focused on proximate accident causes/site-based accident causal factors with a few studies investigating underlying causal factors which emanate from the pre-construction stage of project procurement. As a result of this, although CPFs fall in this category of underlying accident causes, and their causal influence has persistently and appreciably been reported there is still the dearth of detailed insight regarding how CPFs influence accident occurrence, the degree of their potential to influence accident occurrence (i.e. the potential to cause accident) and their associated H&S risk (i.e. the likelihood of accident occurrence).

Given the need to continuously improve the H&S performance of the construction industry through efforts such as those addressing root accident factors, there is the need to bridge these gaps in knowledge regarding the accident causal role of CPFs through research. The next chapter begins this investigation by delving into H&S risk management literature to identity an appropriate means by which the H&S risk associated with CPFs can be evaluated.

# CHAPTER 4: HEALTH AND SAFETY RISK EVALUATION

## 4.0 INTRODUCTION

In the preceding chapter a review of construction accident causation studies was presented highlighting the limited focus on underlying causal factors in construction accidents and also the knowledge gaps relating to the accident causal influence of CPFs. These gaps comprise the lack of detailed insight into: how CPFs influence accident occurrence; the degree of potential of CPFs to influence accident occurrence (i.e. potential to cause accident); and the degree of H&S risk associated with CPFs (i.e. the likelihood of occurrence of accidents due to CPFs). This chapter begins the investigation to bridge these gaps by examining literature on H&S risk to identify a suitable means by which the H&S risk associated with CPFs can be evaluated. An overview of the concept of risk is first presented in this chapter highlighting the various perspectives on risk and risk management. Subsequently, the chapter reviews H&S risk, particularly H&S risk definitions, the H&S risk management process, and methods of H&S risk evaluation. This chapter thus addresses the second research objective which is to undertake a critical review of H&S risk management with the aim of identifying a suitable method for evaluating the H&S risk associated with CPFs.

## 4.1 WHAT IS RISK?

Risk is a very important, yet elusive concept which attracts considerable interest in several disciplines including construction management. The literature on risk is very extensive and an attempt at reviewing this vast literature will certainly be impracticable within the confines of this study. However, risk is reviewed here to some depth to enable the achievement of the second research objective

According to Dallas (2005), the concept of risk has been around for hundreds if not thousands of years as it all started with gambling. Dallas (2005) stated that in the 17$^{th}$ century, a French nobleman who was fond of gambling and mathematics challenged the great mathematician, Blaise Pascal, to solve a two century old puzzle of how to divide the stakes between two players in an unfinished game of chance. Pascal's solution laid the basis for statistical calculations which underpin quantitative risk assessment. Khan and Burnes (2007) claim that the word "risk" is derived from the Italian word 'risicare', which means to dare. Smith *et al.* (2006) also claim that the term risk rather originated from the French word *risqué*, and began to appear in England, in its anglicised form around 1830 when it was used in insurance transactions. In contrast to the claims by Khan and Burnes (2007) and Smith *et al.* (2006), according to Jannadi and Almishari (2003) the word ''risk'' was known in the English language in the 17$^{th}$ century and is believed that it was originally a sailor's term that came from the Spanish Language and meant ''to run into danger or to go against a rock.''

Just as there is no agreement on the history of the concept of risk, there is also no single agreed definition of risk (Aven, 2009b). Risk has been defined in a variety of ways, among which are the following:

1. Risk is the chance that results could be better than expected as well as worse than expected (Li and Love, 1998).
2. Risk is the probability that an adverse event occurs during a stated period of time (The Royal Society, 1991; Edwards and Bowen, 1998).
3. Risk is the chance of an adverse event depending on circumstance (Godfrey, 1996).
4. Risk equals the expected damage or loss (Willis, 2007).
5. Risk equals the expected disutility (Campbell, 2005).
6. Risk is the probability of an adverse outcome (Graham and Wiener, 1997).

7. Risk is a measure of the probability and severity of adverse effects (Lowrance, 1976).
8. Risk is the combination of probability of an event and its consequences (ISO, 2002).
9. Risk is defined as a set of scenarios each of which has a probability and a consequence (Kaplan and Garrick, 1981; Kaplan, 1991; Zio, 2006).
10. Risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain (Rosa, 1998; Rosa, 2003).
11. Risk is an uncertain consequence of an event or an activity with respect to something that humans value (International Risk Governance Council, 2005).
12. Risk refers to uncertainty of outcome, of actions and events (Strategy Unit- Cabinet Office, 2002).
13. Risk is the two dimensional combination of consequences and its associated uncertainties (Aven, 2009a).
14. Risk is uncertainty about and severity of the consequences of an activity, with respect to something that humans value (Aven, 2008).
15. Risk is a threat (or opportunity) which could affect adversely (or favourably) the achievement of the objectives of an investment (Institution of Civil Engineers and The Actuarial Profession, 2005).
16. Risk is a measure of the probability and consequence of not achieving a defined project goal (Project Management Institute, 2008).
17. In the area of flood studies, risk is a function of the probability of a flood hazard, of exposure to the flood hazard, and of the vulnerability of receptors to the flood hazard (Jha *et al.*, 2011).

Given the many different perspectives of risks, it is not surprising that Aven (2009a) noted that the methods used in dealing with risk also vary a lot. Despite this variety, Smith *et al.* (2006) noted that generally, the various definitions of risk are valid depending on the industry or sector or the discipline within which it is being used. It is therefore unnecessary to attempt to point that some definitions of risk are incorrect/invalid and this can be seen from the fact that studies on risk have often only adopted or adapted a particular definition of risk which suit their study context without having to suggest that other definitions are incorrect/invalid (cf. Jannadi and Almishari, 2003; Aven, 2009b).

## 4.2 MANAGEMENT OF RISK IN CONSTRUCTION

Risk exists in construction, the result of which could undermine the achievement of project objectives. The need to effectively manage risk can therefore not be overstated as effective management of risk is central to the achievement of project objectives (Akintoye and MacLeod, 1997; Mills, 2001). Managing risk is not a new concept due to the fact that traditionally it has been applied instinctively (Mills, 2001). Risk management is considered as a "process" and several authors emphasise a systematic approach of this process in construction (cf. Edwards and Bowen, 1998; Tang, 2001; Wang *et al.*, 2004). Definitions of risk management include:

1. Risk management is the art and science of identifying, analysing and responding to risk factors throughout the life of a project and in the best interest of its objectives (Wideman, 1986).
2. Risk management involves three basic elements of organisational control theory: the setting of goals; the gathering and interpretation of information; and action to influence human behaviour (The Royal Society, 1991).
3. Risk management involves the identification of the particular significant risks which may impair the performance of a specific project (Lewis *et al.*, 1992).
4. Risk management is the systematic process of identifying, analysing, and responding to project risk (Project Management Institute, 2008).

5. Risk management is a formal and orderly process of systematically identifying, analysing, and responding to risks throughout the life-cycle of a project to obtain the optimum degree of risk elimination, mitigation and/or control (Wang *et al.*, 2004).
6. Risk management is a process which generically comprises of seven stages which are preparation, identification, analysis, evaluation, treatment, presentation and reporting, and implementation and review (Dallas, 2005).

Despite the differences in steps and terms used by different authors to define risk management as seen from the above definitions, the overall framework for managing risk is largely similar (Cox and Townsend, 1997) and can be considered to consist of four main stages (Baker *et al.*, 1999; Wang *et al.*, 2004) as follows:

- <u>Risk identification</u>: - This is the process of examining the program areas and each critical technical process to identify and document the associated risk (Kerzner, 2009). Lester (2007) indicated that in risk identification the scope of the project and the work breakdown structure is examined and investigated to identify possible risk factors. Some of the techniques in identifying risk factors are brainstorming, reviewing of standard risk lists, and expert opinions.
- <u>Risk analysis/evaluation:</u> - This is the process of assessing the degree of risk associated with the identified risk factors by the use of qualitative, quantitative or semi-quantitative methods (cf. Jannadi and Almishari, 2003; Wang *et al.*, 2004). In terms of quantitative and semi-quantitative methods, the analysis is obviously tied to the definition or expression of risk being adopted as various definitions and expressions of risk have different input variables which determine risk.
- <u>Risk response:</u> - This involves making decisions regarding how to manage the assessed risks. Response options include: risk avoidance, risk reduction, risk transfer, risk sharing, risk deferment, and risk acceptance (cf. Lester, 2007).

- Risk monitoring: - This involves systematic tracking and evaluation of the performance of risk response actions (Kerzner, 2009).

The manner in which these stages are related is shown by Figure 4.1.

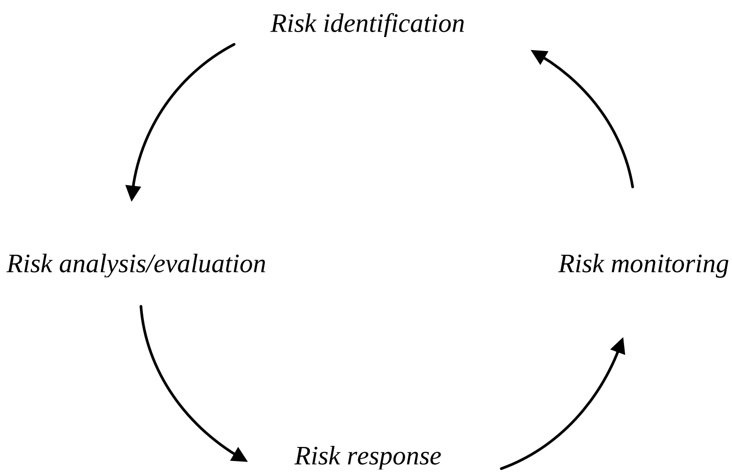



Figure 4.1: Risk management cycle (Adapted from Baker *et al*. (1999) and Wang *et al.* (2004))

It has been noted that systematic risk management improves the likelihood of a project being completed on time, within budget, to the required quality and with proper provision for safety and environmental issues (cf. Mills, 2001). Risk management needs to be carried out throughout the life cycle of a project as risk factors could arise at various stage of a project (cf. Dey and Ogunlana, 2004). Lock (2007) notes that a risk event which occurs late in project delivery can be more costly than a similar event which occurs early. This again underscores the need for effective risk management from the early stages of project delivery to address risk factors early in order to avoid incurring huge costs from those risks factors in a later stage of the project.

Various forms of risk exist in construction projects and these include financial, economic, contractual, technical, environmental, political, and health and safety (cf. Edwards and Bowen, 1998; Dey and Ogunlana, 2004; Lester, 2007). Although each form of risk merits attention in construction management, the H&S focus of this research naturally dictates giving further attention to reviewing H&S risk.

## 4.3 HEALTH AND SAFETY RISK

In terms of H&S, several definitions have also been used for risk. Some of these definitions include:

1. The combination of the likelihood of an occurrence of a hazardous event or exposure(s) and the severity of injury or ill health that can be caused by the event or exposure(s) (British Standard Institute, 2008).
2. A measure of the probability, severity, and exposure of all the hazards of an activity (Jannadi and Almishari, 2003).
3. The likelihood of specific adverse consequences (Risk & Policy Analyst Ltd., 1999).
4. The likelihood of a substance, activity or process to cause harm (Hughes and Ferrett, 2008).

According to HSE (2001; 2006a), risk is the likelihood that harm will occur. As the HSE is the official body for H&S matters in the UK, this definition of risk is adopted for this research.

It has been noted that risk is often interchanged with the term, "hazard", although these two are different (HSE, 2001). Hazard is the intrinsic potential of something to cause harm (HSE, 2001) and the HSE (2001) relates hazard to risk, in this manner: "*risk is the chance that someone or something that is valued will be adversely affected in a stipulated way by a hazard*". Focusing on the H&S of people, and in relation to hazard, risk is thus the likelihood that someone will be harmed (i.e. adversely affected) by a hazard (i.e. the potential of something to cause harm).

Like other forms of risk in construction, H&S risk needs to be properly managed, and with the introduction of regulations such as the CDM Regulations, there has been a huge emphasis on managing H&S risk right from the early stages of project. The need to manage H&S risk is mandatory under the Management of Health and Safety at Work Regulations 1999 (discussed in Section 2.3.1.1). The process of managing H&S risk is similar to the generic framework of risk management (i.e. risk identification, risk analysis/evaluation, risk response, and risk monitoring) although this process is narrowly referred to as "risk assessment" in some literature (cf. HSE, 2006a). The ACoP for the Management of Health and Safety at Work Regulations 1999 (HSE, 2000) and the HSE Guidance document INDG163 (rev2) (HSE, 2006a) recommends steps for managing H&S risk and these steps have been captioned by the HSE (2006a) as, "Five steps to risk assessment". These steps are considered hierarchically below.

### 4.3.1 Hazard Identification

This is the first step and it involves a thorough identification of hazards in the workplace. The HSE recommended tips for identifying hazards include: a tour of the workplace/work area to identify things that could reasonably be expected to cause harm; asking employees or their representatives for their opinion; referring to HSE and trade association guidance on how hazards occur; referring to manufacturers' instructions; and referring to accident and ill-health records (HSE, 2006a).

### 4.3.2 Identifying People at Risk

This step involves identifying the groups of people who might be harmed by the hazard. In doing this, consideration needs to be given to workers with special requirements (e.g. people with disability), people who may not be in the workplace all the time (e.g. visitors), and members of the public (HSE, 2006a).

### 4.3.3 Risk Evaluation and Deciding Risk Control

Authors such as Hughes and Ferrett (2008) prefer to consider risk evaluation as a step separate from deciding risk control measures and as such they propose an overall six step-process instead of five steps. Risk evaluation which is also referred to as, "risk assessment" in some literature (cf. Jannadi and Almishari, 2003; Sachs and Tiong, 2009; Sacks *et al.*, 2009; WHO and FAO, 2009) involves analysing the degree of risk. This is considered in detail below in Section 4.4. After evaluating the level of risk, deciding on the risk control measures to be implemented follows. As some hazards have specific regulations for controlling their associated risk (e.g. electricity, fire, asbestos), those regulations and their accompanying ACoP or guidance should first be consulted. However, in general when deciding risk control measures, a hierarchy of risk controls should be considered in line with the "general principles of prevention" specified in Schedule 1 to the Management of Health and Safety at Work Regulations 1999. The principles are:

- avoiding risks;
- evaluating the risks which cannot be avoided;
- combating the risks at source;
- adapting the work to the individual, especially as regards the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health;
- adapting to technical progress;
- replacing the dangerous by the non-dangerous or the less dangerous;

- developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment;
- giving collective protective measures priority over individual protective measures; and
- giving appropriate instructions to employees.

The common hierarchy of risk control (cf. British Standard Institute, 2008; Hughes and Ferrett, 2008) is:

1. avoidance of risk by elimination or substitution of hazard;
2. reducing or limiting time of exposure to hazard;
3. isolation/segregation of people and hazard;
4. engineering control measures;
5. using safe systems of work;
6. provision of training and information; and
7. using personal protective equipment

### 4.3.4 Recording Findings and Implementing Controls

Recording the findings of the risk assessment is mandatory for workplaces with 5 or more employees although it is still useful for workplaces with fewer than 5 employees to have records of the findings which can be reviewed at a later date. The record should also include details of the groups of people who are affected by the hazards and the control measures. The written record serves as evidence to a H&S inspector of compliance with the law and could be used as evidence should the organisation become involved in a court action. The record should be accessible to employees and a copy kept with the safety manual containing the safety policy and arrangements. In implementing controls, consideration should be given to long-term solutions to those risks with the worst potential consequences; arrangements for training employees; regular checks to make sure that the control measures stay in place; and giving clear responsibilities as to who will lead on what action, and by when (HSE, 2006a).

### 4.3.5 Reviewing and Updating

This involves periodically reviewing the entire process to ascertain any changes and requirements for improvement. Reviews and revisions can be necessitated by changes in workplace conditions as a result of the introduction of new machinery, processes or hazards, the introduction of new legislation, and changes in the workforce. Revision is only necessary if there have been significant changes since the last risk assessment.

As this chapter seeks to identify a suitable means to evaluate the H&S risk associated with CPFs, it is reasonable to consider H&S risk evaluation in greater depth.

## 4.4 EVALUATING HEALTH AND SAFETY RISK

The methods for evaluating H&S risk have mainly been categorised as qualitative and quantitative risk evaluation (cf. British Standard Institute, 2008; Pinto *et al.*, 2011). Popular among the qualitative methods is the checklist/questionnaire method (cf. Pinto *et al.*, 2011). The quantitative methods include failure modes and effects analysis and hazard and operability studies (cf. British Standard Institute, 2008). There are also semi-quantitative or qualitative-quantitative methods which quantify qualitative risk information or use qualitative risk information with corresponding numeric scores (cf. Aven, 2008; Sachs and Tiong, 2009; WHO and FAO, 2009). A popular method of semi-quantitative risk evaluation is risk combination matrix (cf. Risk & Policy Analyst Ltd., 1999; WHO and FAO, 2009) which some authors prefer to classify as a quantitative method (cf. Hughes and Ferrett, 2008).

Literature provides examples of application of the different types of H&S risk evaluation methods. For instance, Kariuki and Löwe (2007) developed a qualitative risk evaluation method that systematically identifies human error in process design and the human factors that influence its production and propagation. The New York State Division of Industrial Safety Services used a quantitative method that correlates the degree of risk of various construction activities and the workmen's compensation insurance rates (Knab, 1978). The technique adopted by the New York State Division of Industrial Safety Services was modified by Knab (1978) who developed a model that determines a risk score for various workmen's compensation classifications. Sack *et al*. (2009) developed the construction hazard assessment with spatial and temporal exposure (CHASTE) method which estimates numerically, safety risk level based on: the probabilities of exposure in space and time; an estimate of the probability of a loss-of-control event occurring per worker in crew; the expected severity of the result of potential accident; and the numbers of workers in a crew.

In terms of semi-quantitative risk evaluation, Croner (in Risk & Policy Analyst Ltd. (1999)) presented a task-based method for rating risk using a risk matrix which combines scores for severity and likelihood of hazard (see Table 4.1). The product of these scores provides a risk rating from 1 (very unlikely delay) to 100 (certain/imminent multiple death). The matrix classifies risk as trivial, adequately controlled, and not adequately controlled, on the basis of the need for further action.

Hughes and Ferrett (2008) also presented a risk matrix (see Table 4.2) which estimates risk by combining severity of harm and likelihood of harm. The various combinations are assigned a degree of risk as shown in Table 4.2. Jannadi and Almishari (2003) also developed a risk assessor model which determines a risk score for an activity and a justification factor for a proposed remedy. The risk score is estimated based on severity, exposure, and probability which are all determined using qualitative scales (e.g. minor cuts, for severity; occasionally, for frequency of exposure; and likely, for probability), and are tied to quantitative scores or ratings.

Table 4.1: Scores for severity and likelihood of hazard

| **Severity** | **Score** | **Likelihood** | **Score** |
|---|---|---|---|
| Multiple death | 10 | Certain/imminent | 10 |
| Single death | 8 | Very likely | 8 |
| Major injury, disabling illness, major damage | 6 | Likely | 6 |
| Lost time, illness, damage | 4 | May happen | 4 |
| Minor injury, minor damage | 2 | Unlikely | 2 |
| Delay only | 1 | Very unlikely | 1 |

Source: Risk & Policy Analyst Ltd. (1999)

Table 4.2: Risk matrix for severity of harm and likelihood of harm

| | | **Severity** | | |
|---|---|---|---|---|
| | | *Slight (1)* | *Serious (2)* | *Major (3)* |
| **Likelihood** | *Low (1)* | Low risk (1) | Low risk (2) | Medium risk (3) |
| | *Medium (2)* | Low risk (2) | Medium risk (4) | High risk (6) |
| | *High (3)* | Medium risk (3) | High risk (6) | High risk (9) |

Source: Hughes and Ferrett (2008)

The above demonstrates the variety of risk evaluation methods applied in H&S. As noted by several authors (cf. Smith *et al.*, 2006; Pinto *et al.*, 2011), generally the various methods are valid depending on the context of application. However, the various methods have their strengths and weaknesses which should be taken into account when selecting a risk evaluation method. The weaknesses and strengths of the various types and examples of H&S risk evaluation are presented in Table 4.3.

Although qualitative risk evaluation is easy to use, it is subjective and thus makes it difficult for a third party to understand the basis or rational for the evaluation (WHO and FAO, 2009).

Table 4.3: Comparisons of methods of H&S risk evaluation

| **Methods of risk evaluation** | **Example of Method** | **Strength** | **Weakness** |
|---|---|---|---|
| Qualitative risk evaluation | Checklists/ Questionnaires | • Easy to use<br>• Quicker to complete<br>• Use can prevent "missing something" in initial evaluations<br>• Requires no specialised mathematical and computational resources | • Often limited to yes/no answers<br>• The checklist used might not take into account unique situations<br>• It is subjective and thus may be difficult for a third party to understand the basis or rational for the assessment<br>• Mainly used for only prioritising hazards for further analysis |
| Semi-Quantitative risk evaluation / Qualitative-quantitative risk evaluation | Risk matrix | • Relatively easy to use<br>• Quicker to complete<br>• Provides visual representation<br>• Does not require the kind of numerical data used in quantitative methods.<br>• It uses qualitative data with accompanying numeric ratings/scores<br>• Requires fewer specialised mathematical and computational resources | • The evaluated risks are placed into usually quite broad sets of categories |
| Quantitative risk evaluation | Failure modes and effects analysis | • Good for detailed analysis of processes<br>• Allows input of technical data | • Needs expertise to use<br>• Needs precise numerical data to input into analysis which may be unavailable<br>• Takes resources (time and money)<br>• Better for risks associated with equipment than those associated with human factors |
| | Exposure assessment strategy | • Good for analysis of data associated with hazardous materials and environments | • Needs expertise to use<br>• Needs precise numerical data to input into analysis which may be unavailable |

Source: British Standard Institute (2008), Jou *et al.* (2009), Sachs and Tiong (2009), WHO and FAO (2009), and Pinto *et al.* (2011).

Also, qualitative risk evaluation mainly prioritises identified hazards for further analysis and as such does not necessarily give an indication of the likelihood of occurrence of harm (i.e. risk) (WHO and FAO, 2009). A qualitative risk evaluation will thus not be suitable for evaluating the H&S risk associated with CPFs. With quantitative risk evaluation, the major challenge is the availability or completeness of any historical and numerical data needed for the evaluation (British Standard Institute, 2008; Sachs and Tiong, 2009). Previous construction accident causation studies in UK and elsewhere have generally noted the limitations of accident records especially when it comes to studying root accident causal factors which are upstream of the project procurement process (cf. Suraji, 2001; Bomel Limited *et al.*, 2006; Cooke and Lingard, 2011). Given that CPFs fall in this category of accident causal factors, a purely quantitative risk evaluation will also not be a suitable option.

Semi-quantitative risk evaluation provides an intermediary level between the textual evaluation of qualitative risk evaluation and the numerical evaluation of quantitative risk evaluation, by evaluating risks with a score. It offers a more consistent and rigorous approach to evaluating and comparing risks than does qualitative risk assessment, and avoids some of the greater ambiguities that a qualitative risk assessment may produce (WHO and FAO, 2009). It does not require the same mathematical skills as quantitative risk evaluation, nor does it require the same amount of data, which means it can be applied to risks where precise data are missing or unavailable. Semi-quantitative risk evaluation thus appears to be a more suitable approach for assessing the H&S risk associated with CPFs. Semi-quantitative risk evaluation is however not without any weakness. The resulting risk scores are placed into usually quite broad sets of categories (e.g. risk score 0-3 = Low risk, risk score 4-7 = Medium risk, and risk score 8-10 = High risk). This weakness can however be overcome if the categories are carefully constructed (WHO and FAO, 2009). As with purely quantitative risk evaluation, a key aspect of semi-quantitative risk evaluation is the risk expression based on which risk is evaluated. The risk expression indicates the risk determining variables and again several risk expressions exist in the H&S literature. Among the common ones are:

- Risk = likelihood x severity (Risk & Policy Analyst Ltd., 1999; Hughes and Ferrett, 2008).
- Risk = probability x severity x exposure (Jannadi and Almishari, 2003).
- Risk = probability x severity x frequency (Risk & Policy Analyst Ltd., 1999).

Another common and hence widely used expression is, Risk = hazard x Exposure (Chicken and Posner, 1998; Duffus and Worth, 2001; Canadian Centre for Occupational Health and Safety, 2008). By this expression, risk (i.e. the likelihood of occurrence of harm) is a function of hazard (i.e. the potential of a thing to cause harm) and exposure to the hazard. This expression is supported by the argument that unless there is hazard, there cannot be risk (HSE, 2000). The role of hazard in determining risk is emphasised by this: "*risk is the chance that someone or something that is valued will be adversely affected in a stipulated way by a hazard*" (HSE, 2001). The expression also shows that hazard alone does not determine risk but does so through exposure to the hazard. Duffus and Worth (2001) support this with the argument that unless there is exposure to a hazard there will be no risk regardless of the degree of the hazard. Hazard, being the potential of a thing to cause harm, coupled with exposure thus determines risk.

Considering the accident causal influence of CPFs, their potential to influence accident occurrence can be taken as their potential to cause harm, as accidents eventually result in harm - which in the case of this study has been limited to harm to people (i.e. injury and ill-health). The H&S risk associated with CPFs (i.e. the likelihood of occurrence of accident/harm) can thus be considered in terms of the expression, Risk = hazard x exposure, where hazard (i.e. the potential to cause harm) is taken as the potential of CPFs to influence accident. Exposure is the extent to which people or objects are subjected to a hazard (Canadian Centre for Occupational Health and Safety, 2008) and can be assessed in various forms such as duration, frequency, concentration, inhalation and contact (cf. Duffus and Worth, 2001; Canadian Centre for Occupational Health and Safety, 2008). Referring to semi-quantitative risk evaluation as a viable approach for evaluating the H&S risk associated with CPFs, a risk matrix can be used given its wide use and also considering that the risk expression, Risk = hazard x exposure, can easily be applied in a two-dimensional matrix format when adapted for the context of the H&S risk associated with CPFs. In terms of the H&S risk associated with CPFs, the above expression can thus be re-written as:

> *Risk associated with a CPF = The potential of the CPF to influence accident occurrence* ***x*** *Exposure of workforce.*

In order to evaluate the H&S risk associated with CPFs, the next step will be to determine the inputs of the expression and this is considered in the next chapter.

## 4.5 SUMMARY

Risk exists in construction and the need for its effective management cannot be over emphasised. In managing various forms of risk in construction, project participants often apply a generic framework to risk management which comprise: risk identification; risk assessment, risk response; and risk monitoring and review. Specific to managing H&S risk a similar framework has been proposed in the UK which is referred to as the five steps to "risk assessment". It provides useful guidance in managing H&S risk in the workplace including construction.

In the previous chapter it was established that although CPFs are associated with varying degrees of H&S risk, literature does not provide enough insight into this and hence the need to evaluate the degree of H&S risk posed by CPFs. By reviewing literature, it has been shown that the term risk in its general use and also in its application to H&S has no single definition. Just as there is no single definition for risk as applied in H&S, there are also various methods for its evaluation. In evaluating H&S risk the key however is to adopt a definition and method which suit the specific context under consideration and this is demonstrated by the variety of definitions and methods of risk evaluation that have be applied in different H&S studies. For this research, giving consideration to the scope of the study (i.e. UK), the HSE definition of risk has been adopted. Giving consideration also to the strengths and weaknesses of the methods of H&S risk evaluation in the light of the accident causal influence of CPFs, a semi-quantitative method of H&S risk evaluation in the form of risk matrix based on a risk expression which takes into account the degree of potential of CPFs to influence accident occurrence and exposure of workforce has also been adopted. The risk expression offers opportunity for bridging the knowledge gap relating to the degree of H&S risk associated with CPFs. However, further consideration needs to be given to determining the input requirements of the expression and this is addressed in the next chapter.

# CHAPTER 5: CONCEPTUAL MODEL AND MEASUREMENT FRAMEWORK FOR THE ACCIDENT CAUSAL INFLUENCE OF CONSTRUCTION PROJECT FEATURES

## 5.0 INTRODUCTION

In the previous chapter, it was shown that a viable means of assessing the H&S risk associated with CPFs is by a semi-quantitative risk evaluation based on a risk expression that takes into account the degree of potential of CPFs to influence accident occurrence and workforce exposure. The expression provides an opportunity to bring together two facets of the knowledge gaps under investigation: (1) potential of CPFs to influence accident occurrence (i.e. potential to cause accident/harm); and (2) their associated H&S risk (i.e. the likelihood of occurrence of accident/harm). In order for the expression to be applied, there is the need to give detailed thought to determining its components, and a coherent manner of doing this is by developing a measurement framework which unifies the two facets of the knowledge gap and also provides operational details for the components of the expression.

Of relevance to developing such a framework is a coherent understanding of how CPFs influence accident occurrence. This is also a gap in knowledge being addressed by this study. This chapter therefore focuses on developing, first, a conceptual model of how CPFs influence accident occurrence and subsequently a measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. This chapter thus partly addresses the third research objective which is to develop a conceptual model of the accident causal influence of CPFs and to develop a measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk.

## 5.1 HOW CPFs INFLUENCE ACCIDENT OCCURRENCE

There is no specific indication in the extant H&S literature as to how CPFs influence accident occurrence. However, H&S literature may be able to provide some information which could potentially be fitted together to provide some coherent perspective on how CPFs influence accident occurrence. In reviewing the H&S literature with the intent of gaining such perspective, a vital point of call is literature on accident causation models and theories which essentially attempt to simulate how accidents occur in reality. Accident causation models provide a conceptualisation of the characteristics of accidents, which typically show the relationship between causes and effects. They explain how accidents occur, and are useful tools in risk assessment and control, and also in accident analysis to investigate the causes of accidents.

Modelling of accident causation was pioneered by Heinrich (1936) with his development of the domino theory. The domino theory asserts that 88% of all accidents are caused by unsafe acts of people, 10% by unsafe actions, and 2% by acts of God (Raof, 1998). Heinrich (1936) proposed a “five-factor accident sequence” in which each factor would actuate the next step in the manner of toppling dominoes lined up in a row. The sequence of accident factors is given by Figure 5.1.

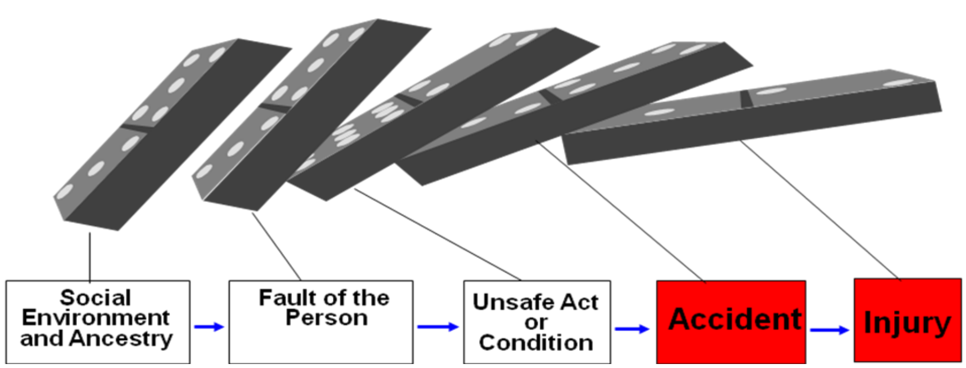



Figure 5.1: An illustration of the Domino Theory (Adapted from Heinrich, 1936)

In the same way that the removal of a single domino in the row would interrupt the sequence of toppling, Heinrich (1936) suggested that removal of one of the factors would prevent the accident and resultant injury; with the key domino to be removed from the sequence being the third domino (i.e. unsafe act or condition). The domino theory is regarded as a useful reference point for safety discussion and a foundation for accident causation studies (Raof, 1998). It was however criticised for overemphasising unsafe acts of people as being the main cause of accidents (cf. Zeller, 1986 cited in Abdelhamid and Everett, 2000).

Following the seminal work by Heinrich (1936) there have been further considerable efforts towards investigating how accidents occur and these have resulted in other accident causation models and theories, generally with the overall aim of providing tools for better industrial accident prevention. Accident causation models may be classified in different ways based on their purpose, area of application, general structure, and key characteristics (Lehto and Salvendy, 1991; Chua and Goh, 2004). In reviewing accident causation models, three prominent categories emerge and are presented below: energy transfer models, individual/human models/theories, and systems models (cf. Laflamme, 1990; Lehto and Salvendy, 1991; Kjellén, 2000; Chua and Goh, 2004).

## 5.1.1 Energy Transfer Models

The energy transfer models view accident causation as the transmission of uncontrolled energy from a source through a path to the victim (Chua and Goh, 2004). Such models suggest that a worker incurs injury or equipment suffers damage through a change of energy, and that for every change of energy there is a source, a path and a receiver. Energy models are useful for evaluating energy hazards and control measures. The control measures could be directed towards the energy source, path of energy transfer and/or the receiver and they could be preventive or ameliorating.

Control of energy transfer at the source can be achieved through:

- elimination of the source;
- changes made to the design or specification of elements of the work station; and
- preventive maintenance.

Regarding the path of energy transfer, it can be modified by:

- enclosure of the path;
- installation of barriers;
- installation of absorbers to absorb the energy; and
- positioning of isolators.

The receiver of the transferred energy can be protected by limiting exposure and by use of personal protective equipment. An example of energy transfer models is the energy transfer model by Haddon (1980). Despite the utility of energy causation models, their view of accident causation is limited given their sole focus on energy transfer without taking into account other important factors such as individual factors, and organisation/management factors (e.g. decisions) which influence accident occurrence (cf. Reason, 1990; Whittington *et al.*, 1992; Hinze, 1996). Again, energy transfer models view accident occurrence as a one-dimensional phenomenon (from energy, through path to a receiver) despite the complexity and multi-causal nature of accidents (cf. Groeneweg, 1994). In terms of providing insight into how CPFs influence accident occurrence, the energy transfer models are thus unhelpful.

### 5.1.2 Individual Causation Models/Theories

The individual theories place emphasis on the direct contribution made by individuals to accidents (Chua and Goh, 2004). They identify the causes and effects of erroneous acts by individuals (usually front-line workers) and they usually focus on the psychological and behavioural aspects of humans (Chua and Goh, 2004). Examples of individual theories of accident causation are the biased liability theory, the accident proneness theory, the stress theory, the arousal/alertness theory, the psychoanalytic theory, and the distraction theory (cf. Hale and Hale, 1972; Hinze, 1996; Raof, 1998).

#### 5.1.2.1 The Biased Liability Theory

This theory asserts that an individual who is involved in any accident increases or decrease his/her liability to subsequent involvement as compared to other workers (Raof, 1998). The involvement in an accident may increase apprehension when circumstances surrounding the accident are perceived to recur. There could thus be the tendency to avoid any similar circumstance of danger in the future. As an accident could result in death, an individual may however not be involved in any subsequent accident. In practice, as an important objective is to protect people from being involved in accidents in the first place, this theory contributes very little towards developing preventive actions for avoiding accidents (Raof, 1998).

#### 5.1.2.2 The Accident Proneness Theory

This theory asserts that within a set of workers, some workers are more liable to be involved in accidents than others (Raof, 1998). Two versions of accident proneness are considered: proneness due to individual innate personal characteristics; and proneness due to critical events in the life of an individual (Hale and Hale, 1972). This theory is generally not accepted and it is felt that even if indeed the theory is supported by any empirical evidence at all, it probably accounts for only a very low proportion of accidents without any statistical significance (Raof, 1998).

### 5.1.2.3 The Stress Theory

The stress theory postulates that accidents are due to task, environment, or individual stressors which reduce the capability of an individual to meet task demands (Brown, 1990). The individual stressors include fatigue and illness and the task stressors include task demands such as information load. Conditions such as heat, cold and noise are among the environmental stressors. This theory gives a narrow explanation of accident causation as it takes no account of underlying causal factors, not even those which may be responsible for the stressors.

### 5.1.2.4 The Arousal/Alertness Theory

The arousal/alertness theory asserts that accidents are due to a lack of alertness on the part of individuals which also derives from individuals' involvement in their work (Brown, 1990). The theory predicts that there is a greater likelihood of accident occurrence when alertness is low (e.g. when a person is bored) and excessively high (e.g. when a person is anxious). Like the stress theory, the alertness theory does not take account of underlying causal factors and as such prevention strategies will only focus on promoting adequate levels of alertness amongst workers.

### 5.1.2.5 The Psychoanalytic Theory

This theory is from the psychoanalytic school of thought (Hale and Hale, 1972). The theory asserts that an accident is a self-punitive act of a person brought about by a number of subconscious processes involving guilt, anxiety, ambition and conflict generated by events in childhood (Suraji, 2001). Accidents are thus viewed to be caused by an individual's psychological background. Given the multi-causal nature of accidents this theory is also a very narrow postulate with which to explain accident causation.

### 5.1.2.6 The Distraction Theory

Hinze (1996) introduced the distraction theory with a specific focus on construction accident causation. The distraction theory asserts that there is a relationship between the likelihood of injury occurrence, productivity, and mental distraction(s) experienced by workers. The relationship between these factors is shown in Figure 5.2.

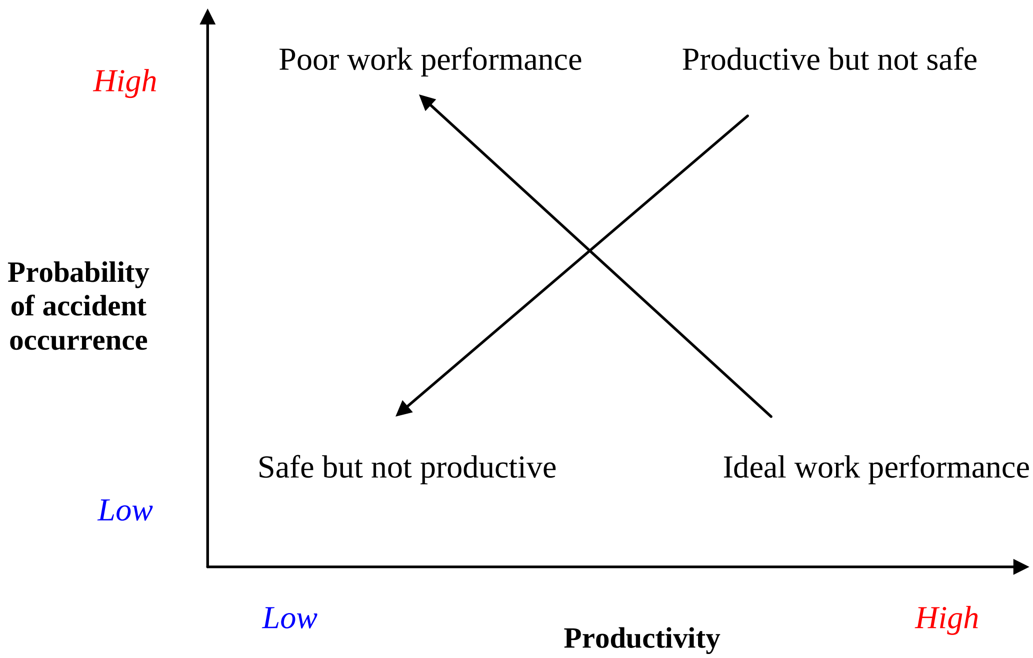



Figure 5.2: The Distraction Theory of Accident Causation (Hinze, 1996)

The theory identifies two sources of distraction: physical hazards; and mental diversions. Physical hazards result in a change in working performance from high to low productivity, and from high to low probability of accident occurrence as shown by the downward inclined arrow. Mental diversions result in a change in working performance from high to low productivity, and low to high probability of accident occurrence as shown by the upward inclined arrow. The theory postulates that when operatives have a high focus on hazards, productivity will be low and probability of accident occurrence will also be low. On the other hand, when operatives have a low focus on hazards, productivity will be high and probability of accident occurrence will be high. The theory also postulates that, when operatives are mentally distracted, productivity will be low and probability of accident occurrence will be high. On the other hand, when operatives are not mentally distracted productivity will be high and probability of accident occurrence will be low. The theory however only considers a single distraction at a time and does not explain the effect of a possible aggregation/combination of both physical and mental distractions on the likelihood of the occurrence of accident (Suraji, 2001).

#### 5.1.2.7 Summary of Individual Causation Models/Theories

Individual causation theories are useful in highlighting the direct role of workers/operatives in accident occurrence. However, their main focus on individual factors restricts consideration of other proximate accident causal factors (e.g. working environment) and underlying causal factors (e.g. management). Individual models thus do not take a holistic view of accident causation. They also do not explicitly facilitate the continual improvement of safety management systems as they do not emphasise the role of organisation and management in accident causation (Chua and Goh, 2004). Given the focus of individual theories of accident causation on individual factors (i.e. immediate accident causes) they are unhelpful in explaining how CPFs influence accident occurrence as CPFs have an underlying causal influence.

### 5.1.3 Systems Models of Accident Causation

Systems models of accident causation have their roots in systems theory. Systems theory includes the principles, models, and laws necessary to understand complex interrelationships and interdependencies between system components (technical, human, organisational and management). The systems models of accident causation refer to models that highlight the role of the organisation and its systems in the causation of accident (Chua and Goh, 2004). The models view accidents as by-products of a production system and they focus on the characteristics of the production system that generate hazardous situations and shape the behaviour of workers (Mitropoulos *et al.*, 2005). Systems models also view accidents as an emergent phenomena, which arise due to the complex interactions between system components (human, technical, organisational and management) that may result in an accident (Qureshi, 2007). Henderson *et al*. (2001) regarded a system-based approach to accident causation as one of the requirements of a successful accident investigation. Mitropoulos *et al*. (2005) also argued that effective causation models need to take a systems view of safety and provide better understanding of how the characteristics of a production system generate unsafe conditions and shape the behaviour of workers. These models are concerned with the underlying mechanisms of accident causation (which are generally latent/subtle), the induced/generated immediate causes and the complex interactions between them. These models thus reinforce the multi-causality of accidents and they take a broader view of accident causation. Examples of systems models are the Pathogen Model (Reason, 1990), the Failure Initiation Model (Whittington *et al.*, 1992), the Loss Causation Model (Bird and Germain, 1996), the Swiss Cheese Model (Reason, 1997), the Accident Root Cause Tracing Model (Abdelhamid and Everett, 2000), the Constraint-Response Model (Suraji *et al.*, 2001), and the ConCA Model (Haslam *et al.*, 2005).

#### 5.1.3.1 The Resident Pathogen/Tripod Model

The resident pathogen / tripod model was developed by Reason (1990). Reason (1990) used the analogy that latent failures in technical systems are directly comparable with resident pathogens in the human body, which combine with local triggering factors such as toxic chemicals to overcome the immune system and produce disease. Based on this view, the resident pathogen/tripod model asserts that the likelihood of occurrence of accident is a function of the number of pathogens (latent failures) within the systems. The more abundant they are, the greater the probability that some of the pathogens will be affected by the combination of local triggers and become sufficient to complete an accident sequence. More complex systems are likely to contain more pathogens and simple systems need fewer pathogens to trigger an accident. The higher a person's position within the decision-making structure of an organisation, the greater is his/her potential to trigger pathogens. Efforts aimed at identifying and neutralising pathogens (latent failures) are likely to have greater safety benefits than those directed at minimising active failures (Reason, 1993). It is thus more effective to remove underlying factors than to remove the immediate causes triggered by the underlying factors (Suraji, 2001). The resident pathogens include design deficiencies, management failures, maintenance errors, component weaknesses, bad procedures and routine violations. The causal structure of the resident pathogen/tripod model is given by Figure 5.3.

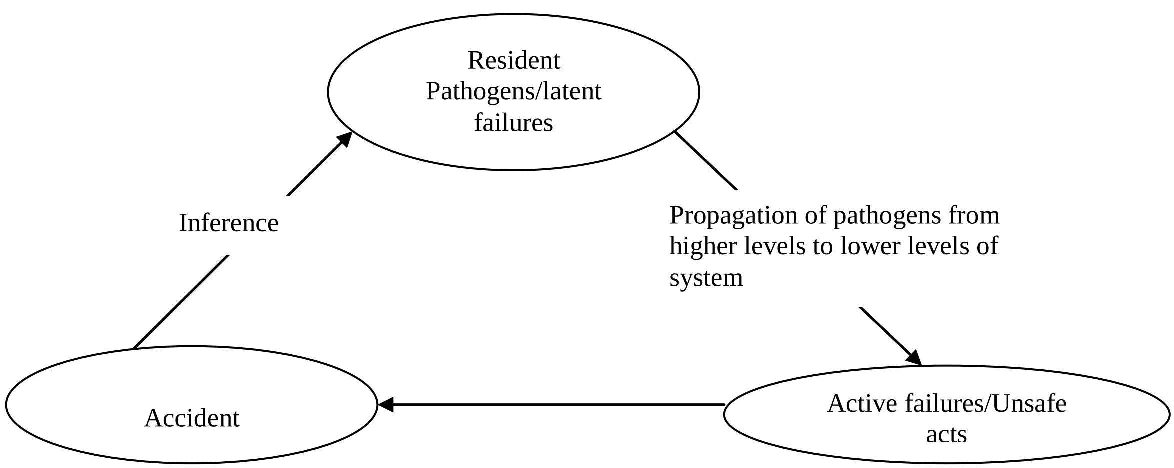



Figure 5.3: An illustration of the Tripod Model of Accident Causation (Adapted from Reason, 1990)

It shows the path of accident causation from resident pathogens through active failures to an accident. The resident pathogens may be inferred from an accident. The resident pathogen model has been useful in advancing subsequent system models of accident causation which focus on the construction context (e.g. the models by Suraji *et al*. (2001) and Haslam *et al*. (2005). Although the resident pathogen model considers the role of management as an underlying cause of accidents, this is considered in the context of an organisation and as such to some extent limits its direct application to the causal influence of CPFs which applies in a project context where various project organisations/participants contribute to accident occurrence.

#### 5.1.3.2 The Failure Initiation Model

Whittington *et al.* (1992) developed a simplified model of accident causation specifically for construction which shows a sequential process of failure initiation. The failure initiation model (as shown by Figure 5.4) reveals causal linkages between four factors: policy failures; project management failures; site management failures; and individual failures. The model illustrates the way in which individual failures by frontline workers leading to accidents can be triggered by policy and project management failures of a contractor. The policy failures include inadequate training policy and poor methods of procurement. Project management failures include lack of planning, poor scheduling of work and choice of inappropriate construction methods. The site management failures include poor communication and lack of supervision. The individual failures include use of wrong equipment and failure to comply with methods of work. Like the tripod model, failures at the company policy level and project management level are considered as latent failures. Like the loss causation model and tripod model, the failure initiation model underscores the role of management in influencing accident occurrence which is important for reviewing and improving safety management systems. The model however assumes that the starting point in accident causation is the stage at which the prime responsibility for safety management has been assumed by a main contractor or some variation of management contractor. The model therefore does not consider the role of client, design and project management at the pre-construction stage in influencing accident occurrence. The model also holds a one-dimensional (i.e. sequential) view of accident causation which does not fully reflect the complexity of accident causation.


Figure 5.4: An illustration of the Failure Initiation Model of Accident Causation (Adapted from Whittington *et al.*, 1992)

### 5.1.3.3 The Loss Causation Model

This model was developed by Bird and Germain (1996) as a modification to the domino theory. The model as shown in Figure 5.5 modifies the first three dominoes to management control, basic causes, and immediate causes. Management control (i.e. inadequate program/compliance to standard) and the basic causes (i.e. personal factors and job factors) act as underlying causes which trigger the immediate causes (substandard acts and conditions). The immediate causes are considered as symptoms of accidents which can be avoided by addressing the basic causes. Given its recognition of the role of management in accident causation, the loss causation model promotes proactive thinking on the part of management. The model thus encourages organisations to accept the responsibility to respond to accidents and not blame it on individuals or physical conditions. Like the domino theory, the loss causation model only holds a one-dimensional (i.e. sequential) view of accident causation which does not fully reflect the complexity of accident causation (e.g. interactions between accident causal factors).

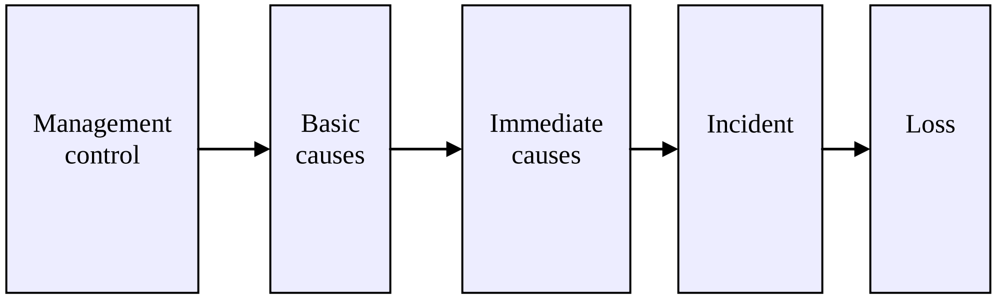



Figure 5.5: An illustration of the Loss Causation Model (Adapted from Bird and Germain, 1996)

#### 5.1.3.4 The Swiss Cheese Model

Building on the concept of the Resident Pathogen Model, Reason (1997) proposed the Swiss Cheese Model as an explanation to organisational accidents (i.e. accidents that happen to organisations). Reason (1997) explained that compared to individual accidents (i.e. accidents where a specific person or group is usually the cause and victim of an accident), organisational accidents tend to be rare but often catastrophic and can affect populations, assets and the environment. The model proposes that organisational accidents occur when layers of defences, barriers, and safeguards erected to withstand hazards are breached or bypassed as a result of active failures and latent failures. These failures create holes (i.e. weaknesses) in the defences and when these holes align, an accident can occur. An illustration of the Swiss Cheese Model is given by Figure 5.6. Although the Swiss Cheese Model is regarded by some writers to have revolutionised understanding of accident causation (cf. Shappell and Wiegmann, 2000) it has not escaped criticism. A main criticism of the model is that it does not fully explain the nature of the holes in the cheese and their inter-relationship (cf. Dekker, 2002; Luxhoj and Kauffield, 2003). Despite such criticism, the model is regarded as being useful in investigating underlying contributors to accidents (Dekker, 2002). However, in terms of helping to explain the underlying accident causal role of CPFs, the focus of the model on an organisational context to some extent limits its applicability as the accident causal role of CPFs relates to a project context where various project organisations can contribute to the occurrence of accidents on a project. Also the model portrays accidents causation in a linear fashion which does not fully reflect the complexity of accident causation e.g. where active and latent failures can be transient/dynamic.

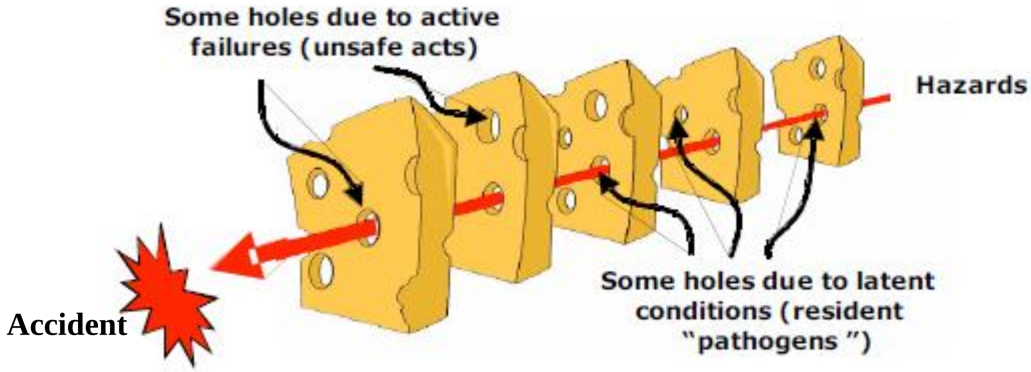



Figure 5.6: An illustration of the Swiss Cheese Model (Adapted from Reason, 1997)

### 5.1.3.5 The Accident Root Cause Tracing Model

Abdelhamid and Everett (2000) developed the accident root cause tracing model for accident causation in construction. The model proposes that accidents occur due to three root causes: failing to identity an unsafe condition that existed before an activity was started or that developed after an activity was started; deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and deciding to act unsafely regardless of initial conditions of the work environment. The model further proposes that unsafe work conditions are due to: management actions/inactions; unsafe acts of worker or co-worker; non-human-related events; and an unsafe condition that is a natural part of the initial construction conditions. Although the accident root cause tracing model acknowledges the role of management (in addition to frontline workers) in accident causation, it focuses mainly on site management and does not extend to capture accident causal factors beyond the construction site. For this reason Suraji and Duff (2000) and Gibb *et al*. (2000) do not consider the accident root cause tracing model as really indicating root causes of accidents in construction.

#### 5.1.3.6 The Constraint-Response Model

This model was developed by Suraji *et al*. (2001) with a focus on accident causation in construction. The model indicates the contribution of all participants in construction projects, from client to site operatives, to accident occurrence. The model postulates that all project participants operate within a variety of constraints as a result of the project environment or behaviour (i.e. responses) of project participants. The constraints trigger responses which can cause inappropriate situations or conditions which increase the risk of an accident. The model presents two hierarchies of causal factors: proximal factors and distal factors. The proximal factors are factors that can lead directly to accident occurrence while the distal factors are those that can, in the event of inappropriate responses by project participants, lead to the introduction of these proximal factors in the construction process. Proximal factors are thus closer to accident events than distal factors which are remote from accidents. The distal factors are similar to Reason's (1990) resident pathogens which trigger immediate causes of accidents. The distal factors include: physical and business environment; project conception constraints; project management constraints and responses; project design constraints and responses; client responses; construction management constraints and responses; subcontractors constraints and responses; and operative constraints. The proximal factors include: inappropriate construction control; inappropriate construction planning; inappropriate construction operations; inappropriate site conditions; and inappropriate operative actions. The constraint-response model indicates inter-causal relationships (i.e. causal interactions) which reflect the complexity and multi-causality of accident causation. Figure 5.7 illustrates the constraint-response model.

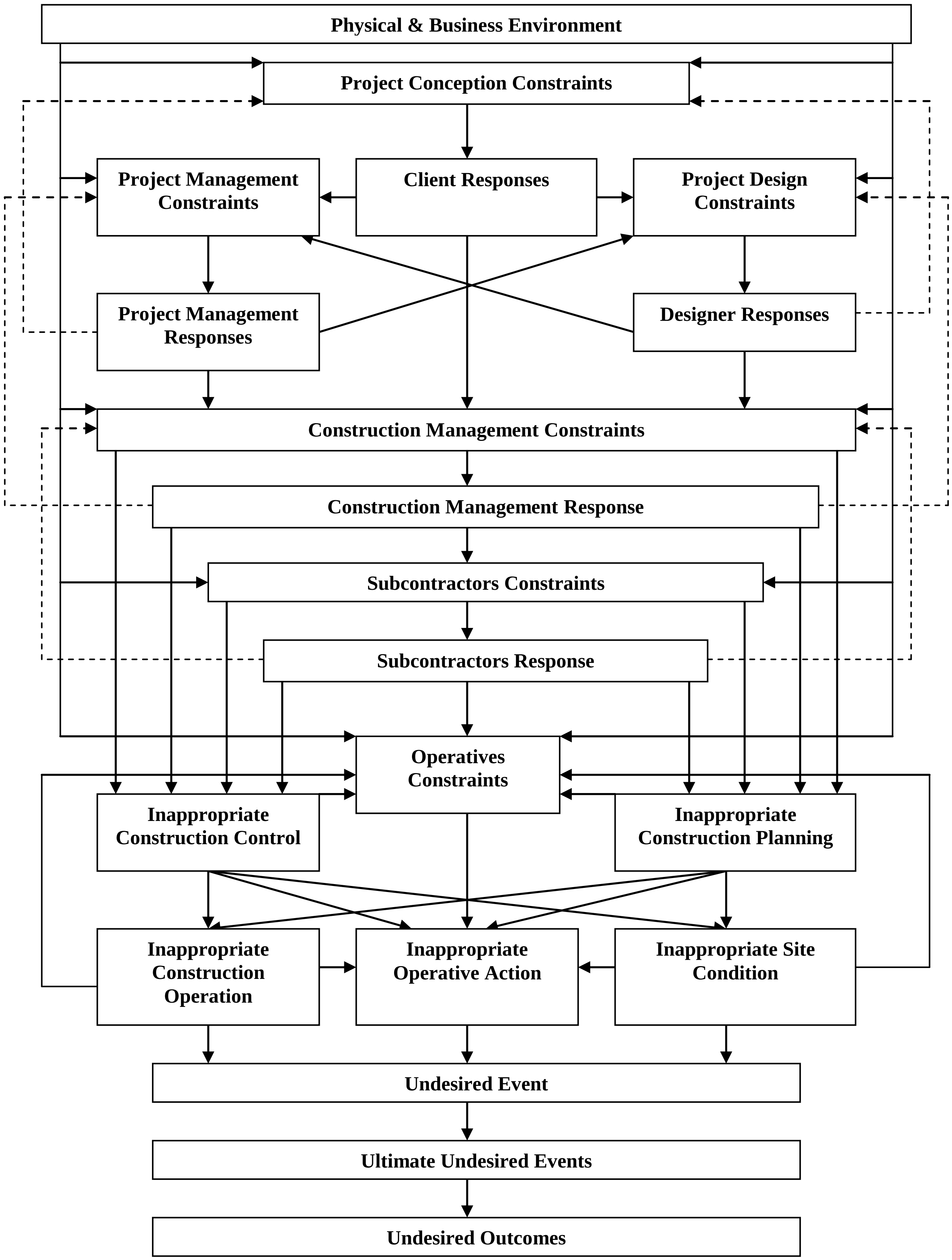



Figure 5.7: The Constraint-Response Model (Suraji *et al.*, 2001)

In general the constraint-response model shows promise in helping to explain how CPFs influence accident occurrence as among other things, it highlights the accident causal role of underlying factors which are upstream of project procurement. The relevance of the constraint-response model to understanding the accident causal influence of CPFs is considered further in Section 5.1.3.8.

#### 5.1.3.7 The ConCA Model

This model was developed by Haslam *et al*. (2005) with a focus on accident causation in construction. Though similar to the constraint-response model in some respect, the ConCA model unlike the constraint-response model indicates three hierarchies of accident causal factors: immediate accident circumstance; shaping factors; and originating influences. As explained by Haslam *et al*. (2005), the immediate accident circumstance arises as a result of a failure in the interaction between the work team, workplace, equipment and materials. The immediate accident circumstance is also triggered by proximal accident factors labelled as, "shaping factors". These shaping factors comprise worker factors (e.g. knowledge/skills and supervision), site factors (e.g. site constraint and housekeeping), and material/equipment factors (e.g. design and specification). The shaping factors are then subject to more underlying factors labelled as, "originating influences", which comprise of the permanent works design, project management, construction processes, safety culture, risk management, client requirements, economic climate and education provision. Figure 5.8 illustrates the ConCA model. Haslam *et al*. (2005) notes that the originating influences are difficult to trace in accident investigation and their influence tends to be subtle/latent and as such could go unnoticed. The originating influences can thus be likened to Reason's (1990) resident pathogens/latent failures which play an essential role in the occurrence of accident.

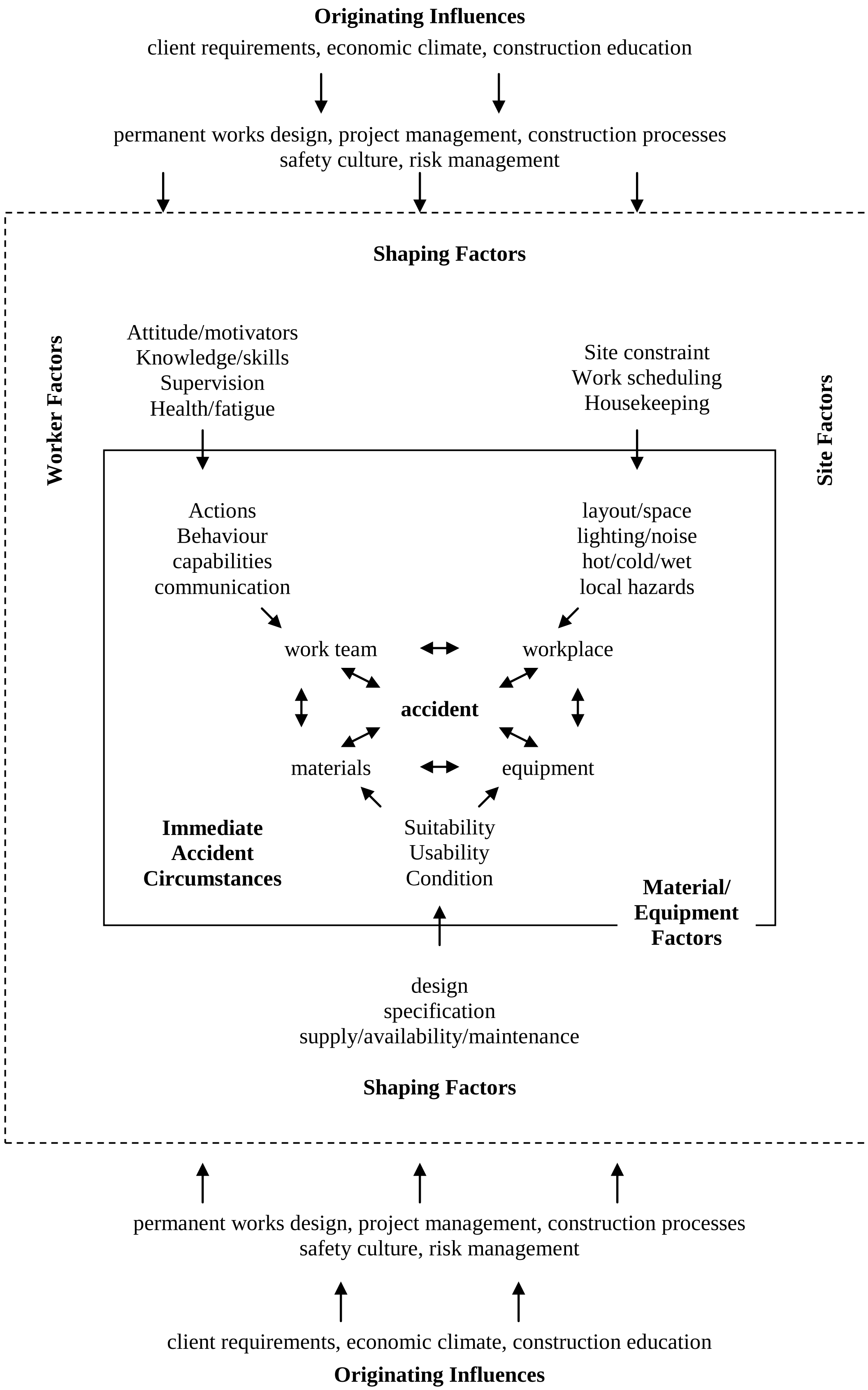



Figure 5.8: The ConCA Model of Accident Causation (Haslam *et al.*, 2005)

The shaping factors and originating influences are also similar to Suraji *et al*.'s (2001) proximal factors and distal factors respectively. Like the constraint-response model, the ConCA model shows promise in helping to explain how CPFs influence accident occurrence given its recognition of deep underlying causal factors which extend beyond the construction phase. The following section examines further the relevance of the ConCA model and Constraint-Response model to understanding how CPFs influence accident occurrence.

#### 5.1.3.8 Summary of Systems Models of Accident Causation

Generally, given their focus on the role of underlying factors in influencing accident occurrence, systems models of accident causation provide scope for explaining how CPFs influence accident occurrence as CPFs play an underlying/root accident causal role. Despite their emphasis on underlying causes, systems models such as the Loss Causation Model, Tripod/Resident Pathogen Model, the Swiss Cheese Model, the Accident Root Cause Tracing Model, and the Failure Initiation Model, view accident causation from an organisation perspective and as such do not reflect the wider context of a project setting where various project organisations (i.e. participants) could contribute to accident occurrence. As a result, their direct relevance in explaining how CPFs influence accident occurrence is limited. Their relevance is also limited by the one-dimensional view of accident causation held by these models which does not fully reflect the complexity of accident causation.

The Constraint-Response model and the ConCA model represent an important progression in understanding accident causation in a project context, particularly in construction. This is because they highlight the causal influence of factors that are upstream of construction project procurement (e.g. decisions by client, designers and project management team) and by that provide the opportunity to address those factors early. By highlighting these factors they also underscore the accident causal influence of key project participants such as the project client, design team, and project management team who occupy a high position in the decision-making structure of project procurement and as such have greater potential to trigger Reason's (1990) resident pathogens (i.e. underlying factors). By emphasizing the contribution of such key project players the models encourage them to accept responsibility for ensuring safety. The models thus drive home the message that accident prevention is not the sole responsibility of the organisations responsible for the physical execution of a construction project but also project participants whose decisions dictate the manner of the physical execution.

Being the result of pre-construction decisions by clients, designers and project management team, CPFs reflect the kind of underlying causal factors described by Suraji *et al*. (2001) as distal factors and Haslam *et al*. (2005) as originating influences. Compared to the other system models of accident causation, the Constraint-Response model and the ConCA model therefore hold greater promise in helping to explain how CPFs influence accident occurrence. Again the Constraint-Response model and the ConCA model acknowledge the complexity of accident causation by their multi-dimensional representation of accident causation which takes into account causal interactions among causal factors.

In summary, the Constraint-Response model and the ConCA model provide a useful basis for developing an understanding of how CPFs influence accident occurrence. As accident causation models are a useful way of explaining how accidents occur, in seeking explanation to how CPFs influence accident occurrence, developing a similar model for the specific context of the causal influence of CPFs is a further extension of this principle. In doing so, the Constraint-Response model and the ConCA model will serve as useful guides.

## 5.2 DEVELOPING A CONCEPUAL MODEL OF HOW CPFs INFLUENCE ACCIDENT OCCURRENCE

In explaining how accidents occur, accident causation models generally identify the accident causal factors, the relationships between them and the path of accident causation. These features of accident causation models are vital as they provide the basis for the development of accident prevention measures. Beyond these essential features, some causation models, in particular the systems models, classify causal factors based on their closeness to an accident event and this facilitates the deployment of targeted preventive efforts to address the categories of accident causal factors (cf. Suraji *et al.*, 2001; Haslam *et al.*, 2005). In conceptualising how CPFs influence accident occurrence, it is essential that the developed conceptual model depicts these key features in its representation of reality.

The conceptual model must also be simple (Fellows and Liu, 2008), though not to the detriment of its depiction of the key features. Models can be graphical or mathematical (Fellows and Liu, 2008). Graphical models are visual and it is the logic they depict which often underpins the development of mathematical models (Fellows and Liu, 2008). As graphical models have largely been used for accident causation models, and they are also common forms of conceptual models used in construction management research (Fellows and Liu, 2008), graphical models shall be applied in conceptualising how CPFs influence accident occurrence in this study.

From the review of the accident causal influence of CPFs presented in Section 3.2, it can be seen that CPFs being the result of pre-construction decisions are inherently associated with certain H&S issues which cause accidents. These H&S issues are summarised in Table 5.1. Compared to CPFs which manifest at the pre-construction stage, these H&S issues manifest during the construction phase where accidents occur. The H&S issues are therefore site-based and hence in terms of proximity to accident events, they are closer than CPFs. Drawing on the generic systems view of accident causation that accidents occur as a result of immediate/proximate causes triggered by underlying causes, the H&S issues associated with CPFs can thus be generally thought of as being "immediate/proximate causes of accidents" which are introduced by CPFs. CPFs can then be considered to influence accident occurrence through the introduction of their associated H&S issues into the construction phase of projects to give rise to accidents.

Table 5.1: Summary of H&S issues associated with CPFs

| **CPFs** | **H&S issues** |
|---|---|
| Nature of project | Uncertainty of hazards (Egbu, 1999; Anumba *et al.*, 2006) |
| Method of Construction | Manual handling, housekeeping problems, and mechanical handling (McKay *et al.*, 2002; Wright *et al.*, 2003; Hughes and Ferrett, 2008) |
| Site Restriction | Site congestion (Hide *et al.*, 2003; Brace *et al.*, 2009) |
| Project Duration | Time-pressure (Hide *et al*., 2003; Brace *et al.*, 2009) |
| Procurement System | Fragmentation of project team (Horbury and Hope, 1999; Brabazon *et al.*., 2000; Hide *et al*., 2003) |
| Design Complexity | Difficulty in constructing (Hide *et al*., 2003; Brace *et al.*, 2009) |
| Level of Construction | Working at height/confined space (Anumba *et al.*, 2006; Hughes and Ferrett, 2008; HSE, 2009a) |
| Subcontracting | Fragmentation of workforce (Mayhew and Quinlan, 1997; Hide *et al.*, 2003; Ankrah, 2007) |

In terms of the Constraint-Response model, these H&S issues, being closer to accidents can be viewed as the "proximal accident factors", similar to the "shaping factors" in the ConCA model. CPFs, given their remoteness to accidents, would then be "distal factors" (in terms of the Constraint-Response model) or "originating influences" (in terms of the ConCA model). The conceived pattern of accident causation by CPFs can be illustrated as shown in Figure 5.9. As depicted by Figure 5.9, CPFs, emanating from pre-construction decisions, influence accident occurrence by their introduction of certain associated H&S issues (which can be termed as proximal factors (PFs)) into the construction phase to give rise to accidents.

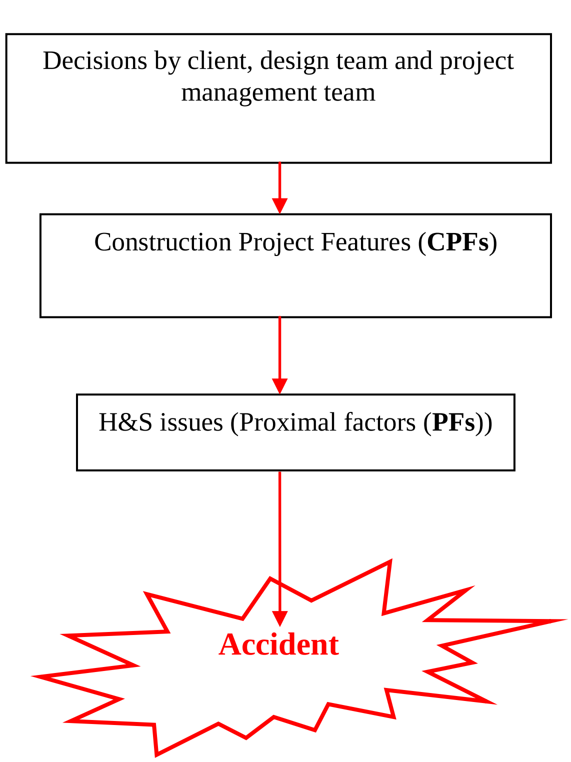



Figure 5.9: Basic pattern of how CPFs influence accident occurrence (Adapted from Suraji *et al*. (2001) and Haslam *et al*. (2005)

Accidents are multi-causal (Hide *et al.*, 2003; Behm, 2005), and applying that to the accident causal role of CPFs, it means that there can be several CPFs contributing to the causation of an accident. In view of this, Figure 5.9 can be further developed as shown in Figure 5.10 to take into account the multi-causality of accidents. Aside the depiction of the multi-causal nature of the causal influence of CPFs given by Figure 5.10, the multi-causal nature could also manifest via the introduction of multiple proximal factors by a CPF as can be seen from the multiple proximal factors (i.e. H&S issues) associated with method of construction (see Table 5.1). Figure 5.10 can also be further developed into Figure 5.11 to illustrate the introduction of multiple proximal factors by a CPF.

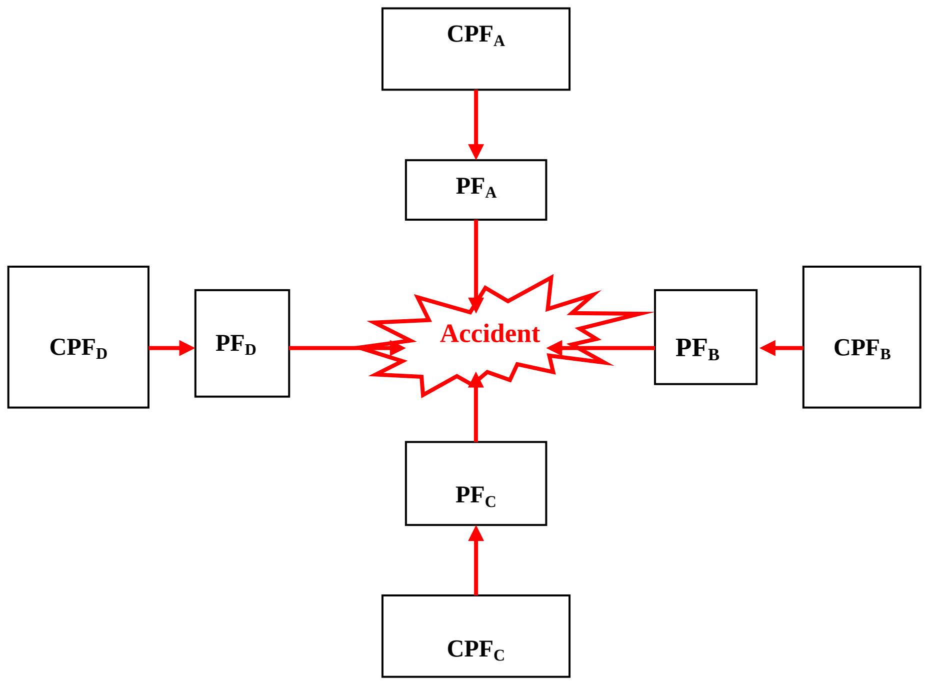



Figure 5.10: Contribution to accident causation by multiple CPFs

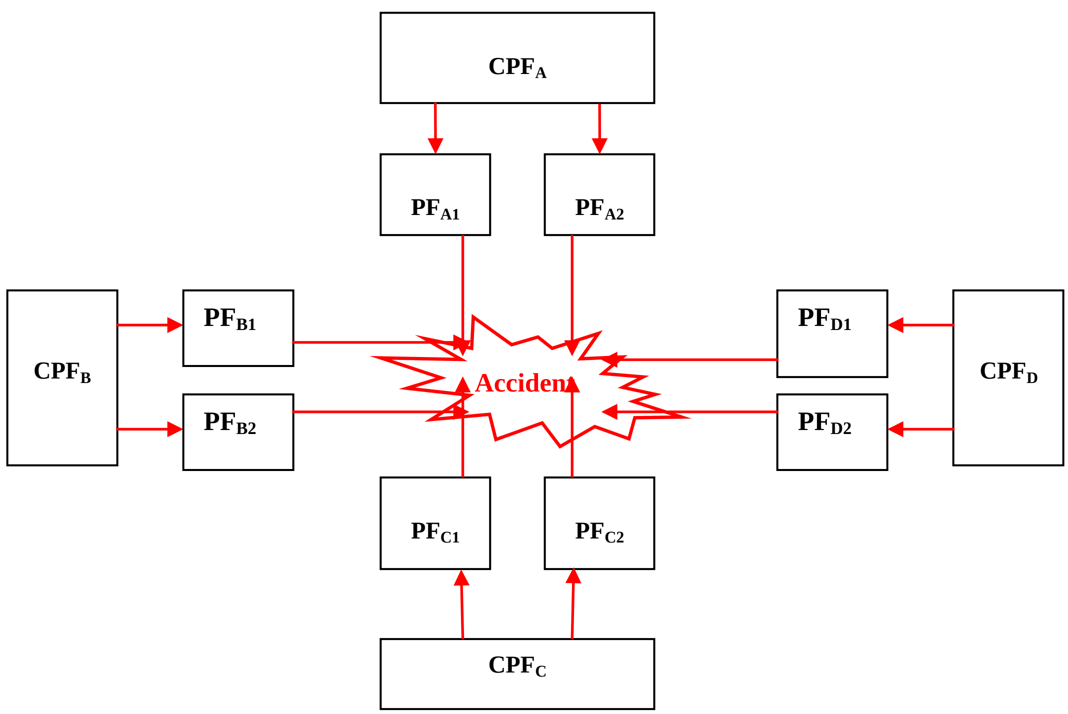



Figure 5.11: Introduction of multiple proximal factors by CPFs

In addition to the path of accident causation (i.e. from underlying/latent causes through proximate causes to accidents) as viewed by systems models, another important aspect of the systems view of accident causation is the existence of causal interactions among causal factors (Qureshi, 2007). These causal interactions epitomise the complexity of accident causation. There is indication in literature that some CPFs can minimise the presence of proximal factors introduced by other CPFs (cf. Wright *et al*., 2003). For instance, Wright *et al*. (2003) reported that a method of construction (i.e. pre-assembly) can achieve time savings and this means that where such a method of construction applies to a project with a tight duration, it could reduce time-pressure introduced by the tight duration. In terms of the systems view of accident causation, this effect can be viewed as causal interactions which transpire between CPFs and proximal factors. Apart from such causal interactions, it can be argued further that there could also be causal interactions among proximal factors. For instance, manual handling on site could increase site congestion as a result of greater labour requirement on site. Taking into account the causal interactions that could transpire between CPFs and proximal factors, Figure 5.11 can be developed further into an accident causation model for the accident causal influence of CPFs as shown by Figure 5.12.

Figure 5.12 can be put forward as an overall conceptualisation of how CPFs influence accident occurrence in line with the systems view of accident causation, in particular the Constraint-Response model and the ConCA model. The conceptual model proposes that CPFs emanating from pre-construction decisions influence accident occurrence by their introduction of proximal causes of accidents which give rise to accidents during the construction phase.

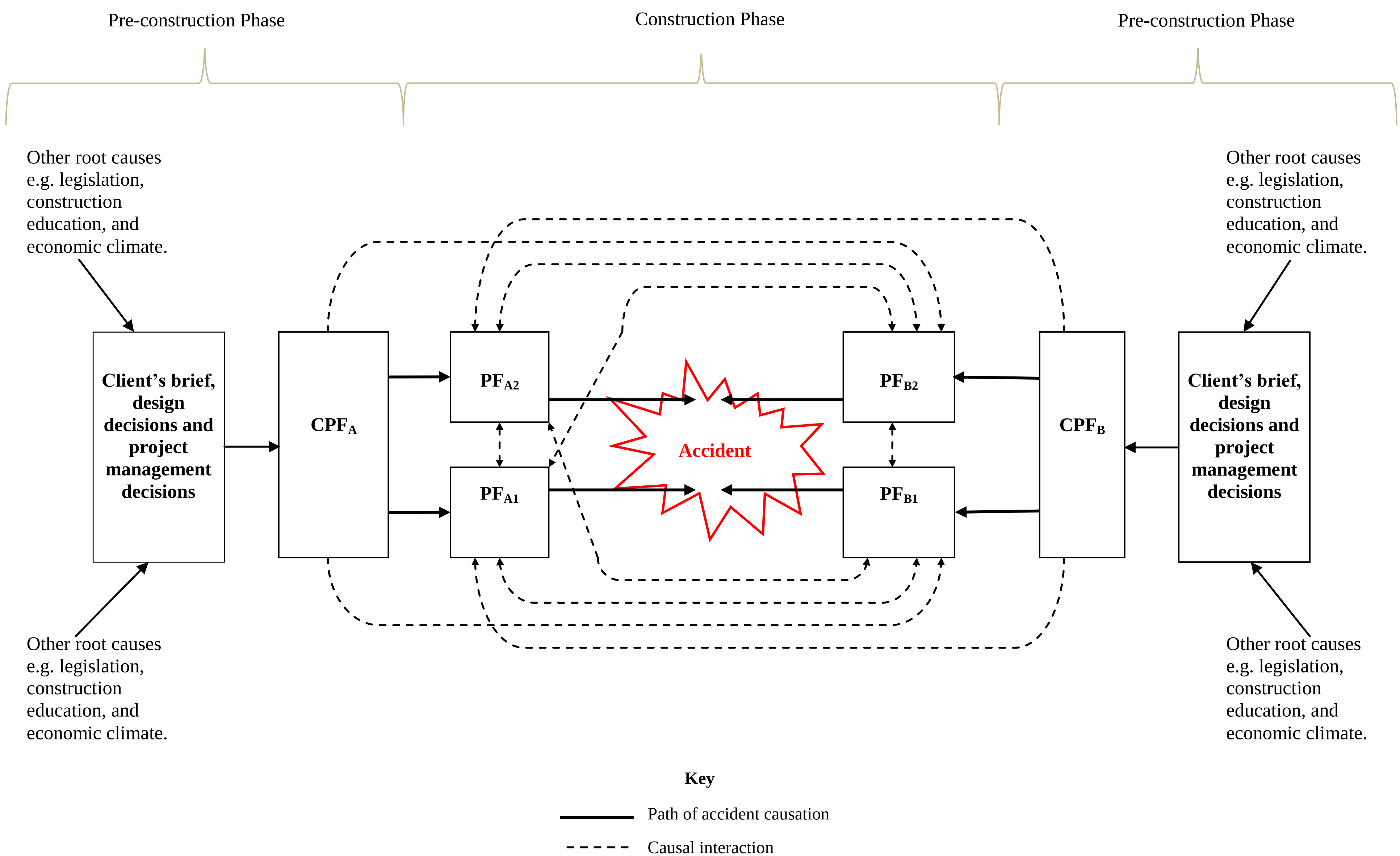



Figure 5.12: A conceptual model of the accident causal influence of CPFs

Aside this path of accident causation, the model also proposes that there are causal interactions amongst CPFs and the proximal factors. CPFs are therefore analogous to Reason's (1990) resident pathogens released by people who occupy a high position in the decision-making structure of an organisation. Subsequent to their release, CPFs then determine the nature, extent and existence of proximate causes of accidents which manifest on site. In terms of the ConCA model, CPFs sit within the originating influences, in particular client requirements, design, and project management and are therefore subject to other root influences such as economic climate and construction education (Haslam *et al.*, 2005). In terms of the Constraint-Response Model, CPFs sit within project management responses, client responses, and design responses which are also subject to root influences from a project's physical and business environment (e.g. legislation, planning restrictions, and difficulty in obtaining project funding) which Suraji *et al.* (2001) describe as project conception constraints. As a contribution to these earlier models, the conceptual model takes CPFs in isolation from among other underlying causal factors and depicts how various CPFs acting collectively on a project could influence the occurrence of accidents. In recognition of the presence of other underlying causal factors, the model however shows causal influence from other root causes such as legislation, construction education, and economic environment.

As previously mentioned, accident causation models are useful tools in the development of accident prevention measures. Based on this conceptual view of how CPFs influence accident occurrence, a key means to address the accident causal influence of a CPF will be to 'block' its release, which means a complete avoidance of the CPF by the pre-construction decision-makers. Where this is not feasible as a result of certain project constraints (e.g. clients requirements), control measures which can eliminate the proximal factors introduced by CPFs could then be considered. As part of considering control measures, potential causal interactions amongst CPFs and proximal factors will also have to be taken into account as such interactions could increase or decrease the presence of proximal factors that will be present on site.

At present, given the conceptual nature of the model, it is pre-mature to indicate conclusively the manner in which accident prevention measures ought to be. It is therefore reasonable to propose an empirical verification of the conceptual model to ascertain whether it is a reliable framework for explaining how CPFs influence accident occurrence. Through such verification, the model also stands to potentially facilitate accident investigation on projects in terms of probing the contribution of CPFs and hence the contributions of pre-construction project participants such as client, design team and project management team. This verification is addressed in the subsequent chapter. Again as decisions regarding the choice of CPFs and other accident prevention measures will have to be based on or weighed against the degree of H&S risk associated with CPFs, it is important for the H&S risk associated with CPFs to be known. The subsequent sections thus present the development of a measurement framework for assessing the H&S risk associated with CPFs. This is done by drawing on aspects of the conceptual model.

## 5.3 DEVELOPING A MEASUREMENT FRAMEWORK FOR ASSESSING THE DEGREE OF POTENTIAL OF CPFs TO INFLUENCE ACCIDENT OCCURRENCE AND H&S RISK

In Section 4.4, the risk expression below was put forward as a viable means of assessing the H&S risk associated with CPFs.

> *H&S Risk associated with a CPF (Rk) = Potential of CPF to influence accident occurrence (C) x Exposure (E).*

The expression indicates two risk determining factors: (1) potential of a CPF to influence accident occurrence; and (2) exposure. Prior to applying this expression, it is important to give detailed consideration to its components and a useful way to do this will be to systematically develop an overall measurement framework which relates in a coherent manner the various components of the expression whiles also providing details for operationalising the expression. The following sections begin this development by examining the risk determining factors in the expression.

### 5.3.1 The Degree of Potential of CPFs to Influence Accident Occurrence

In Section 3.2, the review of the accident causal influence of CPFs showed that CPFs have varying degrees of potential to influence accident occurrence (i.e. some CPFs have greater potential than others as was summarised by Table 3.6). From the review, there also is a suggestion in the literature that these differences in the degree of potential of CPFs to influence accident occurrence are due to a varying extent to which proximal factors (i.e. the H&S issues) are common (in other words, prevalent) within their associated CPFs. This implies that the more common/prevalent a proximal factor is within a CPF the greater the degree of potential of the CPF to influence accident occurrence as shown by the continuum in Table 5.2. From Table 5.2, for instance, a complex design has greater potential to influence accident occurrence than a simple design due to the greater extent to which difficulty in constructing (i.e. buildability) is common within a complex design than a simple design. Also multi-layer subcontracting has greater potential to influence accident occurrence than single-layer subcontracting due to workforce fragmentation being greater within multi-layer subcontracting than single-layer subcontracting.

Table 5.2: The potential of CPFs to influence accident occurrence

| Proximal factors | **Degree of Potential of CPFs to influence accident occurrence** (Extent to which proximal factors are common/prevalent with CPF) Lesser → Greater |
|---|---|
| Uncertainty hazards (Egbu, 1999; Anumba *et al*., 2006) | New work — Refurbishment, Demolition |
| Manual handling, housekeeping problems, and mechanical handling** (McKay *et al*., 2002; Wright *et al*., 2003; Hughes and Ferrett, 2008) | Pre-assembly construction — Conventional construction |
| Site congestion (Hide *et al.*, 2003; Brace *et al*., 2009) | Unrestricted site — Restricted site |
| Time-pressure (Hide *et al.*, 2003; Brace *et al*., 2009) | Unconstrained duration — Constrained duration |
| Fragmentation of project team (Horbury and Hope, 1999; Matthews and Rowlinson, 1999; Brabazon *et al*., 2000; Hide *et al*., 2003; Baiden, 2006; Eriksson, 2010) | Design and Build, Partnering — Traditional — Management contracting |
| Difficulty in constructing (Hide *et al*., 2003; Brace *et al*., 2009) | Simple Design (Simple aesthetic qualities) — Complex Design (Intricate aesthetic qualities) |
| Working at height / Confined space (Hughes and Ferrett, 2008; HSE, 2009a) | Low-level construction — High-level construction, Underground construction |
| Fragmentation of work force (Mayhew and Quinlan, 1997; Hide *et al*., 2003; Ankrah, 2007) | Single-layer subcontracting — Multi-layer subcontracting |

**Pre-assembly construction is generally associated with greater extent of mechanical handling than conventional construction.

The table also suggests that conventional construction having greater potential to influence accident occurrence than pre-assembly construction is due to manual handling and housekeeping problems being more prevalent within conventional construction than within pre-assembly construction, despite mechanical handling being more prevalent within pre-assembly construction. This suggests that in an aggregated sense, the prevalence of all the three proximal factors within conventional construction is generally greater than within pre-assembly construction and thus accounting for conventional construction having greater potential to influence accident occurrence than pre-assembly construction.

Based on Table 5.2, it can therefore be conceptualised that the degree of potential of a CPF to influence accident occurrence (represented by **'C'**) is influenced by the extent to which its proximal factor(s) is prevalent/common within the CPF (represented by **'r'**). Relating the causal interactions that transpire between CPFs and proximal factors (shown in Figure 5.12) to the degree of potential of CPFs to influence accident occurrence, there is indication in the literature that the causal interactions affect the degree of prevalence of proximal factors within CPFs (i.e. '**r**'). For example, where pre-assembly construction is present with high rise construction, a restricted site and/or constrained project duration, the pre-assembly construction can reduce the extent (i.e. prevalence) of working at height, site congestion and time-pressure that would be introduced by the high level construction, the restricted site and the constrained project duration, respectively (cf. Wright *et al.*, 2003).

It can be further argued that the decreasing-increasing (mitigating-aggravating) effect of causal interactions on '***r***' is not static but rather dynamic given the dynamic nature of construction (Hallowell and Gambatese, 2009). An example is the dynamic effect which conventional construction could have on the extent of congestion given that conventional construction involves on-site production. This means that at certain periods (depending on the construction programme) there may be fewer or greater stock piles of materials on site which could increase or decrease the extent of congestion imposed by the restriction of the construction site. This dynamism clearly reflects the complexity of accident causation which Groeneweg (1994) likened to a marble standing on a rough plateau of which the undermining mechanism likely to cause its moving and dropping is unpredictable.

In terms of assessing the degree of potential of CPFs to influence accident occurrence, this dynamism poses a challenge as a changing degree of prevalence of proximal factor within a

CPF (i.e. a dynamic '**r**') would suggest a dynamic degree of potential of the CPF to influence accident occurrence (i.e. a dynamic '**C**') based on the suggested influence of '***r***' on '***C***'. However, in terms of providing insight for H&S planning at the pre-construction stage of projects, an assessment of the degree of potential of CPFs to influence accident occurrence which attempts to incorporate this dynamism will be difficult if not unrealistic given that detailed information of changing on-site operations and conditions are less likely to be known at this stage. Rather, an assessment of the independent degree of potential of individual CPFs to influence accident occurrence will be more practicable. That is not to suggest that knowledge of potential causal interactions between CPFs and proximal factors is unnecessary. Such knowledge could still benefit pre-construction H&S planning without necessarily having to quantify the resultant effects of causal interactions on the independent degree of potential of individual CPFs to influence accident. For instance, decisions regarding a CPF could be based on the awareness that it can minimise the prevalence of other proximal factors or that it can increase the prevalence of other proximal factors.

Taking the conceptualisation a step further, it can also be argued that the potential of a CPF to influence accident occurrence is also influenced by the potential of its proximal factor to influence accident occurrence (represented by '**R**') (Manu *et al.*, 2010). This is based on the logic that it is by reason of the proximal factor causing accidents (i.e. having the potential to cause accidents) that the CPF is able to contribute to accident occurrence as a result of its inherent introduction of the proximal factor. This means that assuming a proximal factor has no potential to cause accident, then regardless of its prevalence within a CPF, that CPF will also not contribute to accident occurrence through its introduction of the proximal factor. This can be likened to the argument by Duffus and Worth (2001) in support of the influence of exposure on risk that, regardless of the degree of a hazard if there is no exposure there will be no risk. Synthesising all these arguments, it can generally be conceptualised that the degree of potential of a CPF to influence accident occurrence (represented by **'C'**) is a combined effect of:

- the extent to which its proximal factor(s) is prevalent/common within the CPF (represented by **'r'**); and
- the degree of potential of its proximal factor(s) to influence accident occurrence (represented by **'R'**).

Unlike the degree of prevalence of proximal factor (i.e. '***r***') which allows for relative comparison among CPFs of the same kind in terms of their degree of potential to influence accident occurrence (as shown in Table 5.2), the combined effect of '***r***' and '***R***' could allow for relative comparison across all CPFs as the combined effect would take into account the direness (in other words the harmfulness) of the proximal factors. Based on this conceptualisation, and using the method of mathematical combination (i.e. multiplication) as used in mathematical risk expressions, it can be posited that, '***C'***, equals the product of *'**r**'* and *'**R**' (i.e.* ***C = r x R****)* (Manu *et al*., 2010). The expression suggests a moderation of the relationship between '***C***' and '***r***' by '***R'*** based on the argument that regardless of the degree of prevalence of a proximal factor within a CPF, if the proximal factor has no potential to cause accident, the CPF will also not have the potential to cause accident. The absence of empirical evidence in support of the conceptualised relationships between '***C'***, '***r'*** and '***R'***, thus points to the need for their empirical verification.

## 5.3.2 Exposure

From the adapted risk expression proposed in Section 4.4, exposure plays an important role in determining degree of risk. Exposure is the extent to which people or objects are subjected to a hazard (Canadian Centre for Occupational Health and Safety, 2008) and can be assessed in various forms such as duration, frequency, concentration, inhalation and contact (cf. Duffus and Worth, 2001; Canadian Centre for Occupational Health and Safety, 2008). Sack *et al*. (2009) suggest that construction workforce exposure to hazard should not be assessed at a generic meta-project level but rather assessed at the level of site activities and the physical context within which they are performed. This form of assessment of workforce exposure is consistent with assessing exposure by duration, frequency, concentration, inhalation and contact. Despite the suggestion by Sacks *et al*. (2009) that workforce exposure should be considered at the level of site activities, the remoteness of CPFs from accident events on site and the latent/subtle nature of their accident causal influence imply that it will be impracticable to consider exposure to CPFs (and hence their potential to influence accident occurrence) at the level of site activities. In other words, it will be impracticable to assess exposure of workforce to the potential of CPFs to influence accident occurrence in terms of frequency, concentration, inhalation, and physical contact as those forms of assessment of exposure are more suited to physical activities, substances or conditions on site (cf. Duffus and Worth, 2001; Jannadi and Almishari, 2003). For instance it will be meaningless and impracticable to consider workforce exposure in terms of the frequency of exposure to design and build procurement and for that matter its degree of potential to influence accident occurrence. Such an approach will similarly be meaningless for the other CPFs.

It will however be more appropriate to consider exposure of workforce to the potential of CPFs to influence accident occurrence at a generic meta-project level such as the duration within which a CPF will apply on a project or broadly in terms of whether or not a CPF applies to a project (cf. Manu *et al.*, 2012a). With the former, for some CPFs (e.g. procurement method) it will be fairly straight forward to assess the duration within which they will apply as the duration will be the same as the overall expected project duration. The challenge however is that for other CPFs such as subcontracting it will be difficult assessing the periods of subcontractor(s) on-site engagement especially from the concept/design stages where there is often little information about detailed on-site operations. For a CPF like high-level/multi-level construction, it will also be difficult knowing exactly when the high-level/multi-level facet of an entire structure commences on site. From the foregoing analysis, a more pragmatic and therefore more feasible approach is to consider exposure in terms of whether or not a CPF applies to a project, so that if a CPF applies to a project it will mean that the workforce will be exposed to its potential to influence accident occurrence and where a particular CPF does not apply to a project the workforce will not be exposed to its potential to influence accident occurrence. For any given construction project, various combinations of CPFs could apply and this depends on the pre-construction decisions made by the client, the design team and project management team. Aside assessing exposure in the proposed manner (i.e. whether or not a CPF applies to a project) being more pragmatic, this means of assessing exposure also sits well with semi-quantitative risk evaluation as it allows for the quantification of qualitative information through the assigning of numeric scores/ratings (cf. Jannadi and Almishari, 2003).

### 5.3.3 A Proposed Measurement Framework

The adapted risk expression ties together two facets of the knowledge gaps being investigated in this study: (1) degree of potential of CPFs to influence accident occurrence; and (2) their associated H&S risk, in a unified coherent piece. Drawing on the above discussion, a measurement framework which unifies these two facets and provides operational details for applying the risk expression can be put forward as given by Figure 5.13.

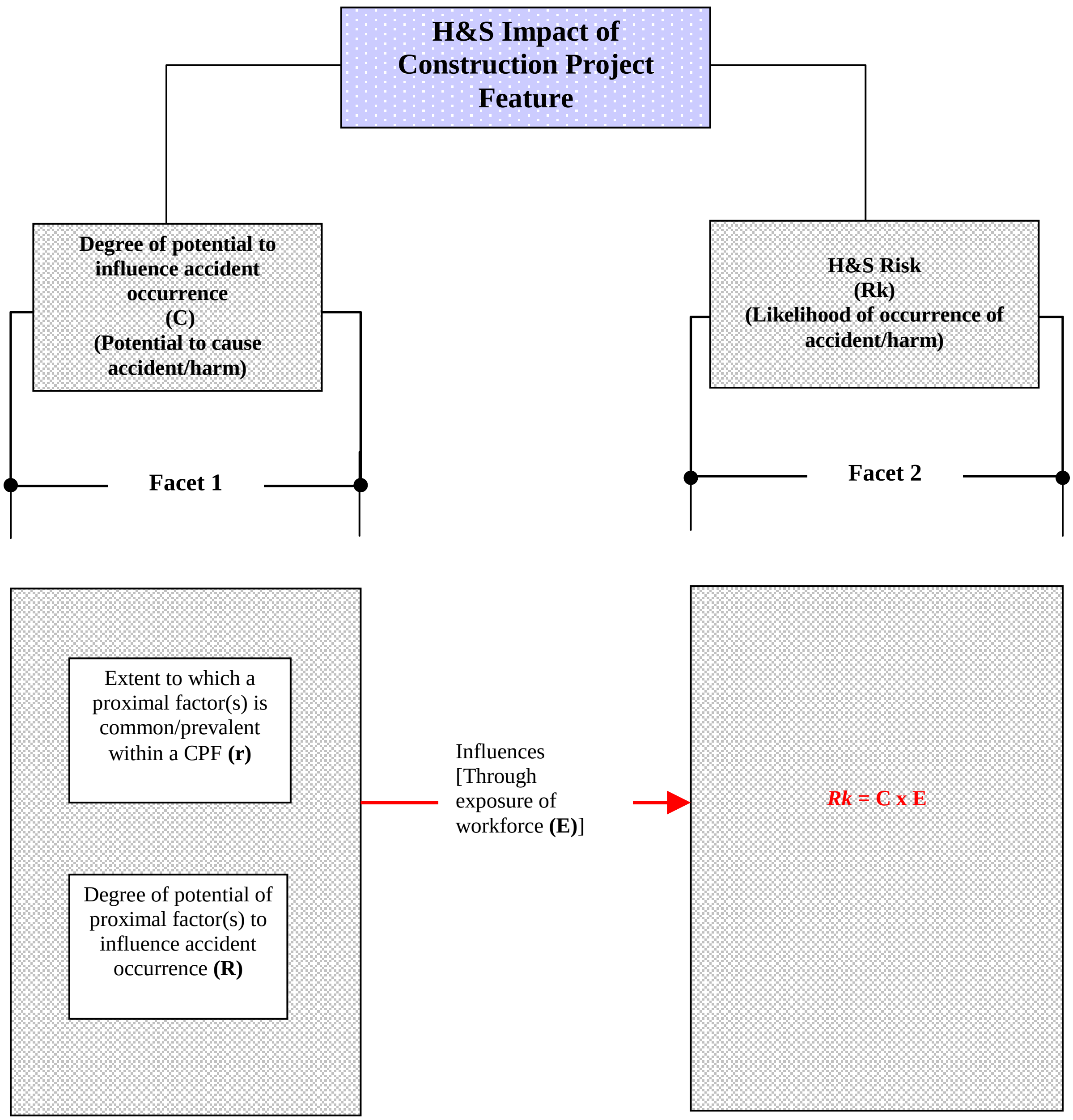



Figure 5.13: Measurement framework

The framework shows that the degree of potential of a CPF to influence accident occurrence (i.e. potential to cause accident/harm) translates into H&S risk (i.e. the likelihood of occurrence of accident) through workforce exposure which can be considered in terms of a

CPF being applicable to a project. The framework suggests that the degree of potential of a CPF to influence accident occurrence is determined by two factors:

- the extent to which its proximal factor is prevalent/common within the CPF (represented by **'r'**); and
- the degree of potential of its proximal factor to influence accident occurrence (represented by **'R'**).

The absence of empirical evidence in support of these conceptualised relationships points to the need for their empirical verification and in pursuit of that it is reasonable to propose some hypotheses. Based on the suggestion in the literature that greater degree of potential of a CPF to influence accident occurrence is due to greater prevalence of proximal factor within a CPF (as summarised by Table 5.2), it is thus expected that:

> *H1: The degree to which a proximal factor(s) is common/prevalent within a CPF will be significantly and positively related to the degree of potential of the CPF to influence accident occurrence.*

It has also been argued (in Section 5.3.1) that if a proximal factor has no potential to influence accident occurrence, its associated CPF will have no potential to influence accident occurrence regardless of the degree of prevalence of the proximal factor within the CPF. This was based on the logic that it is by reason of the proximal factor causing accidents (i.e. having the potential to cause accidents) that the CPF is able to contribute to accident occurrence as a result of its inherent introduction of the proximal factor. This implies that greater degree of prevalence of a proximal factor within a CPF could relate to lower degree of potential of CPF to influence accident occurrence as a result of a lower degree of potential of the proximal factor to influence accident occurrence. Therefore, it is expected that:

*H2: The relationship between the degree to which a proximal factor(s) is common/prevalent within a CPF and the degree of potential of the CPF to influence accident occurrence will be moderated by the potential of the proximal factor(s) to influence accident occurrence such that the relationship becomes more positive as the potential of the proximal factor(s) to influence accident occurrence becomes more positive.*

As the H&S risk associated with CPFs (i.e. $\boldsymbol{Rk = C \times E}$) derives from their degree of potential to influence accident occurrence (i.e. $\boldsymbol{C}$), verification of these hypothesised relationships has implications for H&S risk control. It would provide empirical justification for devising and implementing risk control measures which mitigate the degree of potential of CPFs to influence accident occurrence through the reduction of the prevalence of proximal factors (i.e. $\boldsymbol{r}$) and also the potential of proximal factors to influence accident occurrence (i.e. $\boldsymbol{R}$). Reduction of the potential of proximal factors to influence accident occurrence can practically be conceived in terms of control measures which make proximal factors safer without necessarily removing proximal factors or reducing their prevalence. For instance, measures which can make working at height, manual handling or working in a congested area safer. Such measures could take the form of personal protective equipment (PPE). It should however be noted that in terms of the hierarchy of risk control, measures such as PPE is a last resort and as such reducing the prevalence of proximal factors may be a more viable risk control approach.

Overall, the above measurement framework provides a systematic approach for bridging the knowledge gaps relating to the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. In systematically applying this framework, the degree of potential of CPFs to influence accident occurrence (i.e. facet 1) can first be assessed empirically together with the verification of the proposed hypotheses. On the basis of this assessment, the degree of H&S risk associated with CPFs (i.e. facet 2) can then be evaluated taking into account exposure of workforce. The findings from both phases of the assessment in conjunction with the findings of the empirical verification of the developed conceptual model would then provide the basis for reaching firm conclusions in relation to the knowledge gaps under consideration.

## 5.4 SUMMARY

Advancing towards bridging the gaps in knowledge concerning the accident causal influence of CPFs, this chapter has presented a conceptual model of how CPFs influence accident occurrence, and a measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. The conceptual model which draws on the systems view of accident causation proposes that CPFs influence accident occurrence by inherently introducing associated H&S issues (termed as proximal factors) into the construction phase of projects to give rise to accidents. In addition to this, there are also inter-causal relationships which transpire between CPFs and the proximal factors. The model, like other accident causation models is potentially useful in devising measures for mitigating the accident causal influence of CPFs. However, the conceptual nature of the model implies that there is the need to empirically verify its reliability as a framework for explaining how CPFs influence accident occurrence.

In addition to the conceptual model, drawing on the adapted risk expression from the previous chapter (i.e. Section 4.4), a measurement framework has been proposed depicting a coherent unification of the other gaps in knowledge been investigated i.e. degree of potential of CPFs to influence accident occurrence; and their associated H&S risk. The framework provides a systematic approach for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk, and sets out the operational details. The framework proposes that the degree of potential of a CPF to influence accident occurrence is influenced by two factors: the extent to which its proximal factor(s) is prevalent/common within the CPF; and the degree of potential of its proximal factor(s) to influence accident occurrence. Two hypotheses have thus been posited to empirically verify these claims in order to provide evidence-based justification for devising and implementing effective measures to mitigate the potential of CPFs to influence accident occurrence.

Overall, the conceptual model and measurement framework represent an important progression towards bridging the knowledge gaps relating to the accident causal influence of CPFs. In order to empirically verify the conceptual model and also apply the measurement framework, there is the need for a robust research design which stipulates how data will be collected and analysed, the strategy of inquiry, and their underpinning philosophical position. This is addressed by the next chapter.

# CHAPTER 6: RESEARCH DESIGN

## 6.0 INTRODUCTION

In the previous chapter, a conceptual model and a measurement framework were presented to enable the empirical investigation of the knowledge gaps relating to the accident causal influence of CPFs. This chapter presents the research design adopted for the empirical investigation, in this case a mainly quantitative design incorporating a qualitative inquiry and hence an overall mixed method research design. The justification for choosing this approach and the data collection procedure are also presented. This chapter partly addresses the fourth research objective in terms of identifying a robust research design for verifying the conceptual model and assessing the degree of potential of CPFs to influence accident occurrence (i.e. potential to cause accident/harm) and their associated H&S risk (i.e. likelihood of occurrence of accident/harm).

## 6.1 THE RESEARCH DESIGN

There are several strategies for conducting research and the literature on research methods abounds with contradictory claims regarding the appropriate strategy for a given research problem (cf. Seymour and Rooke, 1995; Rooke *et al.*, 1997; Runeson, 1997; Harriss, 1998; Dainty, 2008). As a result, dilemmas often arise in the process of research, especially when choosing an appropriate research strategy and methods for answering research questions. Creswell (2009) defines research design as the plan and procedures to conducting research involving the intersection of three elements: philosophical worldview (i.e. methodological paradigm), strategies of inquiry (i.e. research strategy), and specific methods (i.e. research methods). Three types of research design are in common use: quantitative; qualitative; and mixed method (cf. Fellows and Liu, 2008; Creswell, 2009). In selecting an appropriate one for a given study, Creswell (2009) proposes that the decision should be informed by the three elements of research design. To aid the choice of an appropriate research design for this study, Creswell's (2009) tripartite framework (as shown by Figure 6.1) served as a useful guide. In the sections that follow, the elements of this framework are reviewed in relation to this study.

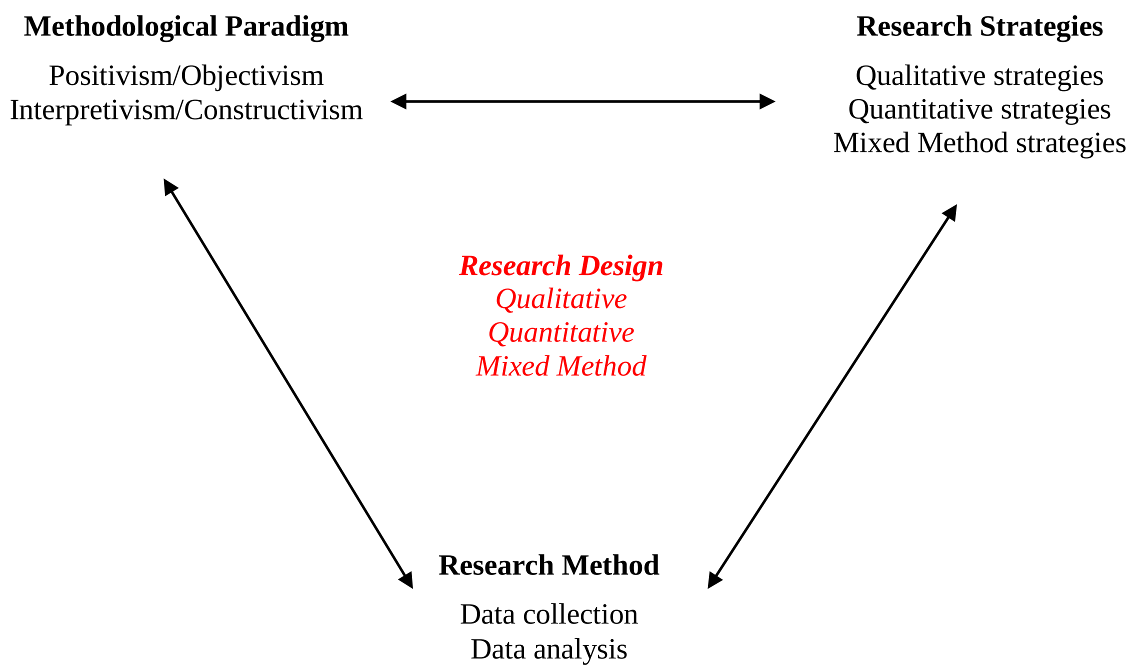



Figure 6.1: Tripartite framework for research design (Creswell, 2009)

## 6.1.1 Methodological Paradigms

According to Pollack (2007), the term paradigm generally refers to "a commonly shared set of assumptions, values and concepts within a community, which constitutes a way of viewing reality." Creswell (2009) uses the term, "philosophical worldview" for paradigm and considers it to mean "a basic set of beliefs that guide action" (Guba, 1990). Although paradigms may be hidden in research (cf. Slife and Williams, 1995), they shape the research strategies and methods adopted by researchers (Pollack, 2007; Smyth and Morris, 2007) and as such need to be identified (Creswell, 2009).

Two prominent research paradigms are in use: positivism; and interpretivism (Bailey, 1987; Fellows and Liu, 2008). Positivism assumes that a phenomenon obeys natural laws and can be subjected to quantitative logic, whiles interpretivism assumes that a phenomenon does not obey natural laws but is interpreted based on peoples' conviction and/or understanding of the reality surrounding the phenomenon (Bailey, 1987; Walliman, 2001). Thus, a positivist believes that the reality can be observed, studied and even modelled, whilst an interpretivist believes that the reality can only be interpreted (Sutrisna, 2009). These paradigms are linked to two main ontological perspectives (i.e. conceptions of reality). The positivist paradigm is linked to the ontological position of single objective reality (i.e. objectivism) whilst the interpretivist paradigm is linked to the ontological position of multiple realities (i.e. constructivism) (Sutrisna, 2009). From the positivist/objectivist perspective, reality can be independently observed as it is single and therefore experienced the same way by everyone. From the interpretivist/constructivist perspective, reality can only be interpreted as it is multiple and therefore experienced differently by everyone.

The choice between positivism and interpretivism has implications in conducting research. Whereas with positivism, the observer is often not part of what is being investigated, with interpretivism, the observer has to be part of the research process. Again, whereas with positivism, the concepts or constructs need to be operationalised so that they can be measured, with interpretivism, the stakeholder interest has to be incorporated. Furthermore, while positivism may require relatively large sample size to draw statistical conclusions, with interpretivism the focus is normally on small samples to help develop in-depth understanding. Table 6.1 provides further contrasting implications of the choice between positivism and interpretivism.

Table 6.1: Contrasting implications between positivism and interpretivism

| **Positivism** | **Interpretivism** |
|---|---|
| The observer must be independent | The observer is part of what is being observed |
| Demonstrates causality | Aim is to increase general understanding of the situation |
| Research progresses through hypothesis/prior formulation | Research progresses through gathering rich data from which ideas are induced |
| Concepts need to be operationalised so that they can be measured | Concepts should incorporate stakeholder perspectives |
| Unit of analysis should be reduced to simplest terms | Unit of analysis may include the complexity of whole situations |
| Generalisation through statistical probability | Generalisation through theoretical abstraction |
| Requires large sample selected randomly | Requires small number of cases chosen for specific reasons |

Source: Easterby-Smith *et al.* (2002)

#### 6.1.1.1 The Research Paradigm Adopted

The research phenomenon under consideration and the key research questions influence the type of paradigm that has to be adopted (Remenyi and Williams, 1998; Pollack, 2007). The conceptual model regarding a phenomenon is also strategic in deciding which paradigm to follow (Miles and Huberman, 1994). Moreover, the conceptual model also forces the researcher to be rational and systematic about the constructs and variables to be included in the research instrument (Ahadzie, 2007). From the research questions posed in Chapter 1, it is evident that they are laden with measurement and therefore in order for objective measurements to be obtained it is logical to adopt positivism as an overarching world view for the phenomenon being investigated (i.e. the accident causal influence of CPFs). By adopting positivism, the degree of potential of a CPF to influence accident occurrence and its associated degree of H&S risk can be viewed as a “single reality” which can then be observed and assessed objectively. The developed conceptual model which is a prior formulation regarding the mechanism by which CPFs influence accident occurrence also sits well with the adoption of positivism.

### 6.1.2 Research Strategies and Methods

Aside the philosophical position adopted in research, researchers also adopt a research strategy and specific methods (i.e. research methods) for collecting and analysing data. The research strategy (i.e. strategy of inquiry), provides specific direction for procedures in a research design (Creswell, 2009). The three common research strategies are qualitative, quantitative and mixed method strategies. These strategies are discussed below.

#### 6.1.2.1 Qualitative Research Strategies and Methods

Qualitative research provides a means of exploring and understanding the meaning individuals or groups ascribe to a phenomenon (Creswell, 2009). It is useful in answering research questions relating to how and why (Fellows and Liu, 2008). The qualitative process of research is inductive in relation to theory and literature and it is usually rooted in the interpretivist/constructivist philosophical position (Sutrisna, 2009). It involves emerging questions and procedures, data typically collected in the participant's setting, data analysis building from particular to general themes, and the researcher making interpretations of the meaning of the data (Creswell, 2009). Qualitative researchers tend to collect four kinds of data: interview data; observation data, document data, and audio-visual data. The common forms of data analysis used in qualitative strategies are text analysis and image analysis. The samples collected are often small as the focus is obtaining in-depth meaning and not generalisation. Despite the usefulness of qualitative research in providing in-depth meaning of phenomena, it has not escaped criticisms from researchers. According to Bryman (2004), critics of qualitative research argue that it:

- is too impressionist and subjective and the findings are based on unsystematic views about what is important and significant;
- is difficult to replicate because it relies on unstructured data and because there are

hardly any standardised procedures to follow, the quality depends on the researcher's ingenuity;

- has problems of generalisation because the scope of qualitative research is often restricted: and
- lacks transparency due to the difficulty which sometimes arises from the establishment of what the qualitative researcher actually did and how the study conclusions were arrived at.

Despite these criticisms, reliability in qualitative research can be achieved by following suggested reliability procedures such as thorough checking of transcripts to ensure they do not contain mistakes, and also making sure there is not a drift in the definition of codes (Gibbs, 2007). Validity can also be ensured by following procedures such as establishing themes based on converging several sources of data or perspectives from participants, allowing participants to comment on the findings, and also using peer debriefing (Creswell, 2009).

Although there are several qualitative research strategies, Wolcott (2001) for instance identified 19 of such strategies and Tesch (1990) identified 28. Creswell (2009) presented five strategies. These five strategies are perhaps the most commonly used and they are succinctly discussed below.

### *Ethnography*

Ethnography is a strategy where the inquirer studies an intact cultural group in a natural setting over a prolonged period of time by collecting primarily observational data (Creswell, 2007). This is deemed an in-depth strategy as the long involvement of the inquirer offers the opportunity to observe not just what people say they do, but what they actually do.

Ethnography is flexible and typically evolves contextually in response to the lived realities encountered in the field setting (LeCompte and Schensul, 1999).

### *Grounded Theory*

Grounded theory is a strategy where the inquirer derives a theory of a process, action, behaviour or interaction grounded in the views of participants in the study (Creswell, 2009). This process involves multiple stages of data collection and the refinement and interrelationship of categories of information (Strauss and Corbin, 1990).

### *Case Study*

Case study is a strategy which encompasses the holistic in-depth study of a phenomenon (e.g. a program, an event, an activity, or a process and one or more individuals) typically using a variety of data sources and procedures (Stake, 1995; Yin, 2003). The cases are bounded by time and activity and researchers collect detailed information over a sustained period of time (Stake, 1995). Yin (2003) provides a useful treatise on the design and implementation of case study strategy.

### *Phenomenological Research*

Phenomenological research is a strategy which involves the study of the ways a person's world view is formed in part by the person who lives it (Fischer and Wertz, 2002). This strategy is therefore concerned with the essence of human experiences about a phenomenon as described by participants (Creswell, 2009). In this process, the researcher sets aside his or her experiences in order to understand those of the participants in the study (Nieswiadomy, 1993).

### *Narrative Research*

Narrative research is a form of qualitative inquiry in which the researcher studies the lives of individuals and asks one or more individuals to provide stories about their lives (Creswell, 2009). The information is then retold by the researcher in a narrative chronology. In the end the narrative combines views from the participant's life with those of the researcher's life in a corroborative manner (Clandinin and Connelly, 2000). Examples of narratives are biographies and autobiographies.

### 6.1.2.2 Quantitative Research Strategies and Methods

Quantitative research is a means of testing objective theories or prior formulations by examining the relationship among variables. It involves numerical and objective measurements to address questions. It is thus useful in answering research questions relating to what, how much and how many (Fellows and Liu, 2008). The quantitative process of research is deductive in relation to theory and literature and it is usually rooted in the positivist/objectivist philosophical position (Sutrisna, 2009). It involves the formulation of hypothesis or prior formulations in the form of a conceptual model based on theory and literature with subsequent collection and analysis of data to verify those prior formulations. Quantitative researchers tend to collect instrument-based data by the use of close ended questioning (e.g. questionnaire) and then use statistical methods to analyse the data to reach conclusions. The samples collected are often large and representative. This means that quantitative research results can be generalised to a larger population.

Quantitative research has also received criticisms from researchers and these are outlined by Bryman (2004) as:

- failure of quantitative researchers to distinguish between people and social institutions from the natural world;
- artificial measurement process and a sense of precision and accuracy not proceeding from the true or claimed source;

- reliance on instruments and procedures that hinders the connection between research and everyday life; and
- creation of a static view of social life that is independent of people's life in analysing the relationships between variables.

Despite these criticisms, quantitative research has shown to be a useful form of inquiry when applied appropriately with respect to the purpose of an inquiry and the questions to be addressed. There are two prominent quantitative strategies: survey; and experiment. These are briefly discussed below.

### *Survey*

This strategy provides a quantitative or numeric description of trends, attitudes, or opinion of a population by studying a sample of that population (Creswell, 2009). It includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection with the intent of generalising from a sample to a population (Babbie, 1990). In a cross-sectional survey, all the data on relevant variables are collected at the same time or within a relatively short time frame. It therefore provides a snapshot of the variables included in the investigation at one particular point in time. On the other hand, in longitudinal surveys, data is collected over long periods of time. Measurements are taken on each variable over two or more distinct time periods. This permits the measurement of change in variables over time.

### *Experiment*

This strategy seeks to determine if a specific treatment influences outcome (Creswell, 2009). This impact is assessed by providing a specific treatment to one group and withholding it from another and then determining how both groups scored on an outcome (Creswell, 2009). In an experiment, investigators may also identify a sample and generalise to a population; however, the basic intent of the experiment is to test the impact of a treatment or an intervention on an outcome, whilst controlling all other factors (i.e. the determinants or causes - independent variables) that might influence that outcome (i.e. the effect - dependent variable) (Creswell, 2009). Experiments are used in both physical and social sciences. In the physical sciences the experiment is laboratory-based. In the social sciences, however, the experiment is field-based.

### 6.1.2.3 Mixed Method Strategies and Methods

Mixed method research is an amalgam of qualitative and quantitative strategies in a single study (Tashakkori and Teddlie, 1998; Morse, 2003). It therefore involves the use of both qualitative and quantitative methods of data collection and analysis in a single study (Creswell, 2009). Mixed method research is normally appropriate in research programmes where due to the nature of the research problem being investigated, it is possible to collect both qualitative and quantitative data, the analysis of which would offer a better and deeper understanding of a phenomenon (Creswell, 2009).

Mixed method strategies are less well known than either the quantitative or qualitative research strategies as the concept of mixing different methods originated in 1959 when Campbell and Fisk used multi-methods to study validity of psychological traits (Creswell, 2009). Recognising that all methods have limitations, researchers felt biases inherent in any single method could neutralise the biases of other methods. The idea of mixing data was initially to seek convergence across qualitative and quantitative methods (Jick, 1979). However by the early 1990s, the idea of mixing moved to actually integrating or connecting the quantitative and qualitative data. There are three main mixed method strategies (Creswell, 2009) and these are as follows.

### ***Sequential Mixed Method***

With this strategy, the researcher seeks to elaborate on the findings of one method with another method. This may involve beginning with a qualitative strategy (e.g. qualitative interviews) for exploratory purposes and following up with a quantitative strategy (e.g. a questionnaire survey) (Tashakkori and Teddlie, 1998). Creswell (2009) terms this approach as the *sequential exploratory strategy*. Creswell (2003) provides an example of a scenario in which this approach can be situated *viz*; where for instance the researcher wants to both generalise the findings to a population and develop a detailed view of the meaning of a phenomenon, the researcher may first explore generally in a qualitative manner to learn about what variables to study, and then study those variables with a large sample of individuals quantitatively. Again, the sequential exploratory mixed method strategy enables the researcher to develop an instrument (e.g. a questionnaire) to be subsequently administered to a sample of the population (Tashakkori and Teddlie, 1998; Creswell, 2009).

Alternatively, the study may begin with a quantitative strategy (e.g. a questionnaire survey) followed by the collection and analysis of qualitative data (Tashakkori and Teddlie, 1998). This procedure is termed the *sequential explanatory strategy* by Creswell (2009). The purpose of sequential explanatory strategy typically is to use qualitative results to assist in explaining and interpreting the findings of a primarily quantitative study (Creswell, 2009). It can be especially useful when unexpected results arise from a quantitative study. In this case, the qualitative data collection that follows can be used to examine these surprising results in more detail.

### ***Concurrent Mixed Method***

Tashakkori and Teddlie (1998) term this approach as the *parallel/simultaneous mixed design.* Unlike sequential strategies where the researcher begins with one strategy (quantitative or qualitative) and follows with another (quantitative or qualitative) in stages, in concurrent strategy, the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research problem (Creswell, 2009). In this design, the investigator collects both forms of data at the same time during the study and then integrates or merges the information in the analysis and interpretation of the overall results (Tashakkori and Teddlie, 1998; Creswell, 2009). Concurrent mixed method can result in well-validated and substantiated findings and also results in a shorter data collection time period compared with the sequential strategy. The concurrent strategy however requires great effort and expertise to adequately study phenomenon with two separate methods and it can be difficult to compare the results of analysis using data of different forms (Creswell, 2009).

***Transformative Mixed Method***

In this strategy the researcher uses a theoretical lens as an overarching perspective within a design that contains both quantitative and qualitative data. The theoretical perspective can be based on an ideology (Creswell, 2009). Within this lens, could be a data collection method that involves a sequential or concurrent approach. Due to the paucity of written work on this strategy, one weakness is that there is little guidance on how to use the theoretical lens to guide the methods (Creswell, 2009).

### 6.1.2.4 The Adopted Research Strategy

Given that quantitative research is usually rooted in the positivist paradigm (Creswell, 2009; Sutrisna, 2009) which is the adopted paradigm for this study, the quantitative strategy naturally emerges as a main strategy of inquiry for this research (Creswell, 2009; Sutrisna, 2009). The suitability of quantitative inquiry for answering questions relating to what, how much and how many (i.e. measurement) further reinforces its suitability for this research given that the research questions put forward in this study largely suggest measurement. Again, the wish to have a generalised view regarding the degree of potential of CPFs to influence accident occurrence and their associated H&S risk (which could inform pre-construction H&S planning) sits well with the quantitative strategy as it is appropriate for making generalisations. Furthermore, the need to test the espoused hypotheses regarding the potential of CPFs to influence accident occurrence is consistent with the quantitative approach. In the main, the quantitative research strategy thus appears to be a prime strategy for delivering this research.

Despite the suitability of the quantitative approach for this research, the need to verify how CPFs influence accident occurrence, also introduces an aspect of a qualitative inquiry given that such inquiry is more useful for answering questions relating to *how* and *why* (i.e. meaning) (Fellows and Liu, 2008; Creswell, 2009). Although the conceptual model is a prior formulation, it essentially attempts to explain a phenomenon (i.e. *how* CPFs influence accident occurrence) and as such its verification could be achieved through a qualitative inquiry. The need to mainly measure and test hypotheses (implying quantitative inquiry) coupled with the need to seek explanation regarding a phenomenon (implying a qualitative inquiry) in a single study then point to an overall mixed method research strategy.

As the conceptual model explaining how CPFs influence accident occurrence was instrumental in shaping the measurement framework (encompassing the hypotheses), it is logical that prior verification of the model (through a qualitative inquiry) precedes the deployment of the measurement framework (in a quantitative inquiry) so that any eventual refinement of the elements of the model could be incorporated in the deployment of the measurement framework. In view of this, the sequential exploratory mixed method strategy emerges as the most appropriate mixed method research strategy for this research. As the initial qualitative inquiry of the sequential exploratory strategy enables the researcher to develop an instrument to be subsequently administered to a sample of the population (Tashakkori and Teddlie, 1998; Creswell, 2009), this strategy would be useful in developing any needed instrument as part of implementing the measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk.

As noted by Creswell (2003), the sequential exploratory strategy allows the researcher to both generalise the findings to a population and develop a detailed view of the meaning of a phenomenon. For all these reasons, this strategy was thus adopted for this research. The application of this approach in construction management studies is not uncommon. This approach was for instance adopted in some quite recently completed construction management doctoral studies (cf. Ankrah, 2007; Tuuli, 2009). Specifically referring to H&S studies, this approach has also been applied (cf. Langford *et al.*, 2000). For instance, Langford *et al.* (2000) in their study used qualitative interviews in conjunction with literature to identify the variables to be studied in a more extensive inquiry using a survey instrument. The results of the qualitative phase fed into their development of the survey instrument.

An outline of the sequential exploratory mixed method approach as applied in this study is shown by the research plan in Figure 6.2. The overarching positivist and quantitative focus of this study implies that the reasoning of the research is largely deductive and this is consistent with the development of a conceptual model and measurement framework which are prior formulations based on literature. The preliminary phase of the research plan (which has been addressed by Chapters 2 to 5) entailed the review of literature which brought to the fore the gaps in knowledge regarding the accident causal role of CPFs.

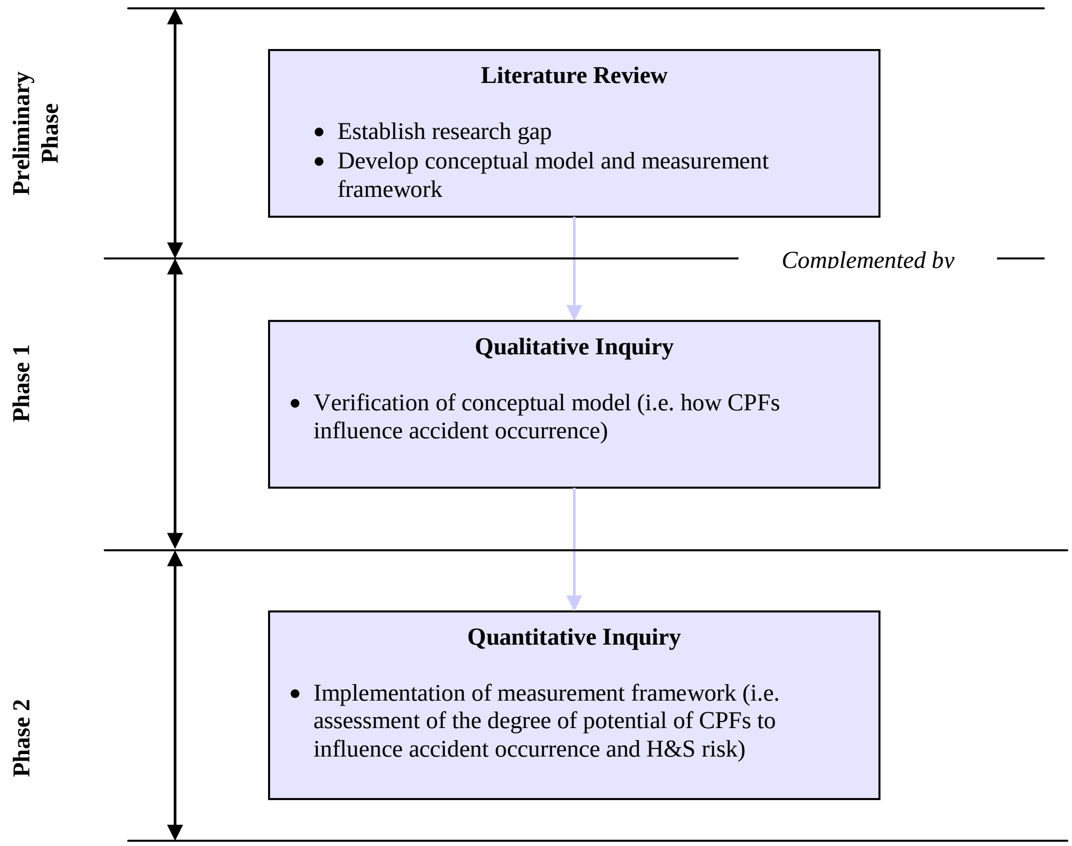



Figure 6.2: Overall research plan

As a step towards filling these gaps, three research questions were posed (i.e. How do CPFs influence accident occurrence? What is the degree of potential of CPFs to influence accident occurrence? What is the degree of H&S risk associated with CPFs?). In the quest to answer these questions, the research aims were articulated followed by the outlining of systematic steps, in the form of specific research objectives, to the achieve the research aims.  Key among the objectives are the development of the conceptual model and the development of the measurement framework in Chapter 5. The conceptual model is geared towards addressing the research aim regarding the mechanism by which CPFs influence accident occurrence and by so doing answering the research question, “How do CPFs influence accident occurrence?” The measurement framework which has two facets is also directed towards addressing the research aim (and hence the research questions) regarding the degree of potential of CPFs to influence accident occurrence and their associated degree of H&S risk. As part of the assessment of the degree of potential of CPFs to influence accident occurrence, two hypotheses, in relation to factors that have been suggested to affect the degree of potential of a CPF to influence accident occurrence, have been put forward for testing. A diagrammatic representation showing how all the key aspects of the research are tied together is given by Figure 6.3.

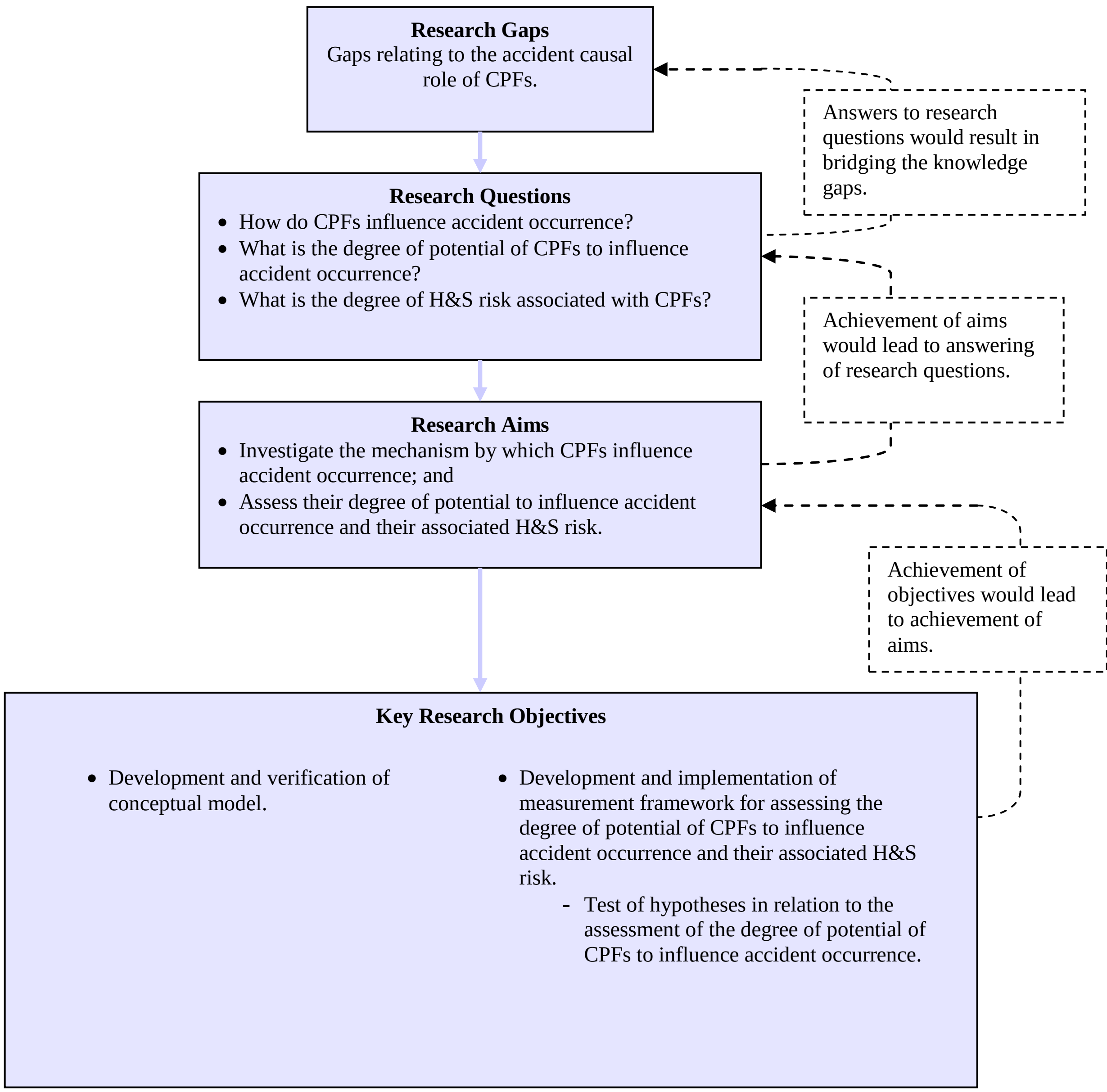



Figure 6.3: Illustration of the relationship between the key aspects of the research

In other to achieve the overall research aims and hence obtain answers to the posed research questions, the qualitative and quantitative inquiries given by the overall research plan (i.e. Figure 6.2) now need to be undertaken.

## 6.2 THE QUALITATIVE INQUIRY

Qualitative inquiry has been strongly advocated for construction management research by Seymour and Rooke (1995) and Rooke *et al.* (1997). The utility of qualitative inquiry as explained by Seymour and Rooke (1995) lies in the deeper understanding of the values and beliefs of others that can be derived by focusing on the points of view of individual practitioners, whilst recognising that the researcher has values and beliefs of their own that cannot be entirely eliminated. Qualitative inquiry is explanatory in nature with the principal aim of trying to answer questions relating to how and why (Fellows and Liu, 2008) or trying to develop themes from the data (Creswell, 2003).

In the previous chapter, a conceptual model which attempts to explain how CPFs influence accident occurrence was presented. In seeking explanation as to how CPFs influence accident occurrence it is thus necessary to empirically verify the soundness of the model as a framework for explaining how CPFs influence accidents. The use of qualitative inquiry to verify a conceptualised view of a phenomenon in construction management research is not uncommon (cf. Ankrah, 2007; Tuuli, 2009) and in fact, Creswell (2009) notes that in other disciplines such as health science it is also common practice for researchers to use qualitative inquiry to verify a prior formulation such as theory. In general terms qualitative inquiry has also been used in accident causation studies as can be seen from the review of accident causation presented in Chapter 3. For instance, Choudhry and Fang (2008) examined why operatives act unsafely using qualitative interviews with operatives, and Hide *et al.* (2003)

used focused group interviews involving site managers, senior managers, safety professionals, clients, operatives and other industry professionals as part of their inquiry into causal factors in construction accidents. As part of investigating the link between management and organisational factors and accidents, Whittington *et al*. (1992) used interviews with project managers. Gherardi *et al*. (1998) also investigated causes of accidents by interviewing construction site engineers and site managers.

Following the precedent set by other accident causation studies with regard to the use of interviews in investigating accident phenomenon, the use of interview was adopted for this phase to explore the accident causal phenomenon of CPFs in order to verify if CPFs influence accident occurrence as conceptualised. Interviews vary in their nature and can be structured, semi-structured or unstructured (Patton, 2002; Legard *et al.*, 2003). Wisker (2001) considers these types of interviews to constitute a continuum, as shown in Figure 6.4, with unstructured and structured interview at the extreme and semi-structured in between. The main characteristics of structured, semi-structured and unstructured interviews are summarised in Table 6.2.

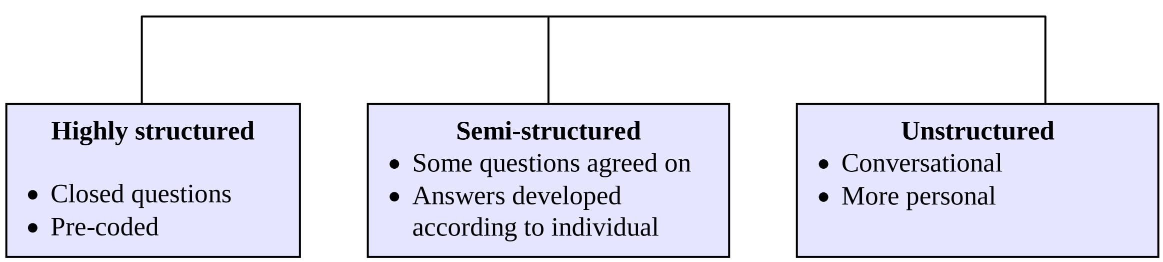



Figure 6.4: The interview continuum (Wisker, 2001)

Table 6.2: Main characteristics of interview types

| Type of interview | Main characteristics |
|---|---|
| **Structured** | - data collected through formal style of questioning;<br>- little scope for probing responses;<br>- supplementary questions required to obtain more details and pursue new aspects;<br>- respondents choose an answer from alternatives; and<br>- same wording and question for all interviewees; |
| **Semi- structured** | - data collected through both formal and informal styles of questioning;<br>- responses can be written and supplemented with recording;<br>- responses limited to subject in question but interviewee is free to add more details if the need be;<br>- provides more details about issue being investigated;<br>- respondents provide topical answers; and<br>- all respondents receive the same major issues. |
| **Unstructured** | - data collected through informal style of questioning;<br>- recording responses is most suitable;<br>- respondents say as much as they wish after a brief introduction by the interviewer;<br>- they can be monologues with few prompts to ensure completion of statements;<br>- answers are provided by respondent in any order they so wish; and<br>- brief introduction of same key issues to all respondents. |

Sources: Patton (2002), Legard (2003), Bryman (2004) and Fellows and Liu (2008)

This research adopted a semi-structured interviews approach as it allows in-depth and free flow of information from interviewees whilst at the same time providing a framework/guide for conducting the interview. The flexible nature encourages the interviewee to participate fully and more comprehensively (Schensul *et al.*, 1999; Patton, 2002; Fellows and Liu, 2008). This approach is thus more comprehensive and more systematic in collecting data and anticipated data gaps can be closed. This also makes organisation and analysis of data relatively easy.

### 6.2.1 Semi-Structured Interviews

In line with the systems view of accident causation, the conceptual model in its depiction of how CPFs influence accident occurrence has two fundamental features: (1) path of accident causation (from underlying causes through proximate causes to accidents); and (2) causal interactions between causal factors. In verifying the conceptual model as a sound depiction of how CPFs influence accident occurrence, the main objective of the interviews was thus to explore experts' opinion, knowledge and experiences of the accident causal influence of CPFs with the intention of eliciting these key features. The interviews also explored experts' opinion, knowledge and experiences of accident causation with regards to the systems view of accident causation discussed in Section 5.1.3. As common with conducting semi-structured interviews, an interview schedule (as shown in Appendix B-2) was developed to guide the interviewing process. It is important to emphasise that this schedule only served as a guide, and the interviewer was free to probe and ask questions in any order as appropriate. It is also important to emphasise that there were no direct questions as to how CPFs influence accident occurrence as conceptualised. Rather, the questions were indirectly posed and the two keys features were subsequently inferred from the responses. For instance it was broadly asked if from their experience, the experts realise any influence of the CPFs being investigated in the occurrence of accidents. The experts were also questioned about the H&S measures they implement on projects and whether implementing those measures was influenced by the features of the project. These questions brought to the fore the accident causal influence of CPFs and made it possible to extract relevant issues relating to the path of accident causation and the causal interactions between accident factors.

#### 6.2.1.1 Selection of Participants

In construction, as contractor personnel are usually those who experience and/or witness accidents they, especially those in construction management roles (e.g. H&S manager, project manager, construction manager and site manager), were mainly targeted for the interview. As there is no organised database for such professionals, it was considered that a viable means of reaching them would be through their employers' contacts (i.e. contractors).

Using the UK Kompass online directory, 50 UK contractors operating in the West Midlands Region of UK were randomly selected and sent letters to solicit participation in the interviews. In the invitation (as given in Appendix B-1) a request was made for a professional in construction management role (e.g. H&S manager, project manager, construction manager or site manager) to participate in the interview. H&S is a very sensitive subject in the UK due to the legalities surrounding it and for that matter obtaining participation in H&S research is difficult (cf. Gibb *et al.*, 2002). Given this terrain, it was also deemed necessary to use industry contacts (some of which the researcher met at construction events) to obtain participation in the interviews. Using industry contacts eventually proved to be very useful. Through the invitation and contacts in industry a total of 11 participants were obtained and interviewed. The participants comprised experienced practitioners of construction firms and a construction health and safety consultant. The demographic information of the participants is provided in Table 6.3.

Table 6.3: Demographic information of participants

| **No.** | **Role of Participant** | **Years of experience in construction** |
|---|---|---|
| 1 | Construction health and safety consultant | 30 |
| 2 | Health and safety manager | 10 |
| 3 | Project manager | 34 |
| 4 | Site manager | 20 |
| 5 | Health and safety manager | 10 |
| 6 | Senior site manager | 29 |
| 7 | Civil engineer & director | 36 |
| 8 | Health and safety manager | 20 |
| 9 | Project manager | 42 |
| 10 | Construction manager | 13 |
| 11 | Project manager | 45 |

The 11 participants were not obtained at once. After the 9th interview, saturation was reached. However, because prior arrangement had already been made with the 10th and 11th interviewees, the interviews were conducted. The entire interviews were conducted from October 2010 to February 2011. As a means of refining the interview guide prior to the interviews, a pilot interview was conducted with a part-time construction management undergraduate student. This provided a useful opportunity to refine the questions and the logical flow of the questions in the guide. The pilot also gave a fair idea of the length of the interview. The main interviews were audio-taped and on average took approximately 60 minutes.

#### 6.2.1.2 Analysis of Interviews

Qualitative data analysis is a challenging process and requires creativity and systematic searching (Baiden, 2006). To aid the analysis, Creswell's (2009) guide for qualitative data analysis was useful. The analysis followed 5 main steps as follows:

- transcribing of the audio interviews (i.e. verbatim transcription)
- organising and preparing the transcripts
- iterative re-reading of the transcripts
- coding of the transcripts; and
- generating themes

Coding transcripts can be by manual means or by computer software (Creswell, 2009). Manual coding can be done when the volume of data is manageable, and computer software is very useful for large volumes of data (Miles and Huberman, 1994; Spencer *et al.*, 2003; Seale, 2005). In this case, the coding was done manually by colour coding (Creswell, 2009) as the volume of data from the 11 transcripts was manageable. Another consideration about coding is whether the researcher uses: emerging codes (i.e. developing codes based on the emerging information); predetermined codes in the form of a qualitative codebook based on theory or a prior formulation being examined; or a combination (Creswell, 2009). Creswell (2009) recommends that where researchers have a theory/prior formulation to be examined, a preliminary qualitative codebook should be developed for coding the data and then permit the codebook to develop. This recommendation was followed. The systematic iterative re-reading and coding of the transcripts enabled the attainment of a profound understanding of each interviewee's view point and hence the extracting of issues and generation of themes relating to the phenomenon under investigation.

### 6.2.1.3 Reliability and Validity Checks

Demonstrating reliability and validity in qualitative research is important in establishing confidence in the findings and conclusions. Qualitative validity means that the researcher checks for the accuracy of the findings by employing certain procedures, and qualitative reliability indicates that there is consistency in the researcher's approach (Gibbs, 2007).

Reliability was ensured by applying the following suggestions by Gibbs (2007):

- checking transcripts (through iterative re-reading) to make sure that they do not contain mistakes made during the transcription; and
- making sure that there is not a drift in the meaning of the codes during the coding process.

Qualitative validity was ensured by applying the following suggestions by Butterfield *et al.* (2005) and Creswell (2009):

- working directly with the verbatim transcript and demonstrating grounding of the findings in the interviewees' responses by providing sample quotes in the respondents' own words;

- referring to the extant literature for support of the findings as a means of demonstrating theoretical agreement which Maxwell (1992) refers to as the presence or absence of agreement within the community of inquirers about the descriptive and interpretive terms used;
- developing themes based on converging several perspectives from the participants;
- peer debriefing by research supervisors who reviewed and questioned the entire qualitative inquiry; and
- member checking by asking the participants to comment on the findings. Due to time constraint this was done together with validation of the quantitative inquiry.

By applying the above validity and reliability checks, an attempt was made to address calls on researchers to utilise qualitative methods with rigour in order to enhance the validity of their studies.

## 6.3 SUMMARY

In the previous chapter, a conceptual model and measurement framework were put forward. Verifying the conceptual model and implementing the measurement framework requires a robust research design which encompasses: research paradigm; strategy of inquiry; and specific research methods. Adopting an overarching positivist paradigm the research has employed a mainly quantitative and hence deductive strategy with the incorporation of an aspect of qualitative inquiry. This has led to an overall sequential exploratory mixed method research design with an initial qualitative inquiry followed by a quantitative inquiry.

The qualitative inquiry which is geared towards addressing the mechanism by which CPFs influence accident occurrence through verification of the conceptual model employed semi-structured interviews with experienced construction professionals. The findings of this prior inquiry are presented in the next chapter together with how the findings feed into the development of the succeeding quantitative inquiry.

# CHAPTER 7: QUALITATIVE FINDINGS AND SUBSEQUENT DEVELOPMENT OF THE QUANTITATIVE INQUIRY

## 7.0 INTRODUCTION

In the previous chapter a sequential exploratory mixed method research strategy underpinned by a positivist world view was adopted for the empirical verification of the conceptual model and the implementation of the measurement framework. The adopted strategy comprises an initial phase of qualitative inquiry which feeds into a subsequent phase of quantitative inquiry. Having presented the data collection and analysis aspects of the qualitative inquiry in the previous chapter, this chapter now presents the findings of the qualitative inquiry and the subsequent development of the quantitative inquiry. This chapter therefore partly addresses the fourth research objective in terms of presenting the findings of the empirical verification of the conceptual model and subsequently presenting the development of an instrument to collect data for the assessment of the degree of potential of CPFs to influence accident occurrence (i.e. potential to cause accident/harm) and their associated H&S risk (i.e. likelihood of occurrence of accident/harm).

## 7.1 RESULTS OF THE QUALITATIVE INQUIRY

The key findings of the qualitative inquiry are presented below under three main headings: construction accident causation; the accident causal influence of CPFs; and how CPFs influence accident occurrence. Parts of these findings have been published in Manu *et al.* (2011a; 2011b)

### 7.1.1 Accident Causation in Construction

The analysis showed that the occurrence of construction accidents is generally viewed by the interviewees to be the result of immediate causes which could be triggered by underlying causes. The responses of the interviewees also pointed that whereas immediate causes tend to be relatively obvious, underlying causes are much more difficult to identify when investigating the causation of accidents. For instance, regarding the role of underlying causes in accident causation and the difficulty in identifying such causes comments such as these were made:

> "*…Root causes are very important. One can have a fall from height. It might simply look like they slipped off a ladder but then, you start to question why the person slipped"* [H&S Manager].

> "*Immediate causes are usually fairly obvious…finding root causes in the first place is definitely the hardest bit*" [H&S Manager].

In addition to the basic path of accident causation i.e. from underlying causes through immediate causes, it was also acknowledged that accident causation is a complex phenomenon characterised by interrelationships between causal factors. This acknowledgement was in the form of responses to a general question about inter-causal relationships between causes of accidents and also through narratives of accident events. For instance one interviewee portrayed the complex and multi-causal nature of accident causation as:

> "*I think it is a very mixed picture. In some cases, you'd get causes that do influence each other…Definitely, things can definitely interact and increase the chances of an accident taking place without a shadow of doubt and I would imagine that if a statistician put that in, you could put those things that are interacting- you know be synergistic- and the overall effect of those things that are interacting is greater than some of their parts".* [H&S Manager].

Further comments highlighting the complex and multi-causal nature of construction accident causation are presented in Table 7.1.

Table 7.1: The complex and multi-causal nature of construction accident causation

| **Comments on the complex and multi-causal nature of construction accident causation** |
|---|
| "Very often it is four or five things that come together to form the accident and if you can take one of those things out of the chain, the accident wouldn't have happened" [Civil engineer & director] |
| " Without doubt it (i.e. accident) needs all those factors to line up and go together" [H&S manager] |
| "It (i.e. accident occurrence) is a bit of a mix really. Some things could lead from others really" [Site manager] |
| "It (i.e. accident occurrence) can be a murky chain of events leading up to it or it can be something simple" [Construction manager] |
| "Yes, I think it's (i.e. accident occurrence) a combination of factors" [H&S consultant] |

These findings are generally consistent with the systems view of accident causation and the systems models of construction accident causation by Suraji *et al.* (2001) and Haslam *et al.* (2005) which view the occurrence of accidents as the result of inter-causal relationships between immediate and root/underlying causes which usually tend to be latent/subtle and hence more difficult to pin down when investigating the causation of accidents.

In terms of investigating accidents on sites, it became increasingly evident that investigations do indeed try to trace the underlying causes. However it was realised that the investigations focus on the underlying factors within the interviewees' organisations operations and not those factors that extend to the pre-construction stage. This is because, aside the difficulty in establishing causality by those factors, it was felt that they (i.e. the contractors) have no control or very limited control over decisions regarding those factors and hence the need to rather focus on investigating factors they can control. This is demonstrated in the following comment.

> *"Although these influence accident causation, it's difficult to investigate through to them when investigating an incident and even if you are able to, even getting that acceptance will be difficult. If you talk about tight programme, our project manager might say well this is so tight. Do we want to tell a client they are responsible for an*

> *accident because it was a tight programme? They'll think we are just trying to shift the blame…So the messages don't always get through. You almost need somebody independent to look at it and off-course that only happens in serious accidents. You then go back and say actually Mr Client, you do carry some responsibility because you made the decision to build the building in 20 weeks not 25 weeks. But it is very hard for us to come up with that as a conclusion about which we can't do anything about"* [H&S Manager].

It seems from the above statement that there is a disconnect between the construction team and pre-construction project participants (i.e. clients, designers, and project management team) in terms of relaying information about underlying causes of accidents which emanate from the pre-construction stage of projects. This situation could undermine continuous learning by pre-construction project participants about their role in accident causation and hence potentially undermine their ability to positively influence H&S from the early stage of project procurement. Reports in industry point out that pre-construction project participants such as designers are less knowledgeable about H&S matters (cf. Hide *et al.*, 2003) and this may be partly due to the seemingly limited feedback they get on their role in accident causation.

### 7.1.2 The Accident Causal Influence of CPFs

Regarding the accident causal influence of CPFs, the analysis confirmed that nature of project, method of construction, site restriction, project duration, procurement system, design complexity, level of construction, and subcontracting have accident implications as has been previously reported in literature and summarised in Table 3.5. Commenting on some of these features, one interviewee for instance emphasized that:

> *"…A complex project brings more risk, a restricted site brings more risk, a tight duration brings more risk and a high rise also brings more risk but you've got to manage those risks by putting in place the right measures to mitigate those risks."* [Project Manager]

Other comments indicating the accident causal influence of project features are also presented in Table 7.2.

Table 7.2: The accident causal influence of CPFs

| **CPFs** | **Comments on the accident causal influence of CPFs** |
|---|---|
| Nature of project | "Refurbishment projects, compared to new builds are more prone to accidents…This is a green field project…I'll say refurbishment project is more prone to incidents than new builds like this project. However you still have to monitor health and safety." [Project Manager] |
| Method of construction | "The more that can be done off-site the less the risk. I've done modular student accommodation where everything comes fitted out in a complete box and you stack one box on top of another. It's a very quick operation and very safe." [Project Manager] |
| Site restriction | "Without doubt, the restriction of a site influences the occurrence of accident." [H&S Manager] |
| Project duration | "With project duration, if the programme is very tight, definitely it has an impact…" [H&S Manager] |
| Procurement system | "From a health and safety point of view, design and build project is better than traditional procurement." [Project Manager] |
| Design complexity | "This could influence the occurrence of accidents because elaborate designs involve strange shapes, strange curved roofs, and the issue is how you are going to build that." (Site Manager) |
| Level of construction | "High rise, there is definitely a greater risk." [H&S Manager] |
| Subcontracting | "Multi-tier subcontracting is not good. When that happens the people down there become distant from the main contractors." [Site Manager] |

In addition to the above project features, another feature which emerged as having accident implications was *restriction of site locality*. This was drawn from a narrative of an accident and also from elaborations given by interviewees on a closely related project feature which is the restriction of site. Unlike the other project features whose impact on H&S is more likely to be on a project site itself (e.g. injury to workers on site), the impact of the restriction of site locality is more likely to occur as harm to a member(s) of public as it concerns working close to the public as indicated in the following comment.

> *"It was a refurbishment and we were putting a new roof on the podium roof and it was right in the centre of Nottingham City Centre. This worker put his trowel on top of the parapet wall, and then goes back to pick it again. He missed the trowel and eventually knocked it. The trowel went down, hit the pavement and bounced back and hit a lady (i.e. member of general public) in the head. It was unfortunate that we were working in the middle of a city centre. Inner city jobs are usually more dangerous with H&S because they are very tight"* [Project Manager].

On the whole, although it was acknowledged that the above project features have accident implications, an important theme that also ran through the interviews was that it is really down to how the risk associated with these project features are effectively managed right from the early stage of a project. This underscores the significance of effective H&S planning right from the early stages of project procurement (Szymberski, 1997) and the relevance of this study given its focus on contributing to H&S knowledge which could inform pre-construction H&S planning. Despite efforts to emphasise pre-construction H&S planning through the operation of mechanisms such as the CDM 2007 Regulations, some interviewees were of the view that some client organisations are still not very keen on H&S and this can be seen in unrealistic time scales given by some clients for project delivery and also less willingness by some clients to commit (enough) resources to H&S. In this regard, project quantity surveyors were mentioned as playing an important role through the advice they provide to clients on contractor selection. Since project quantity surveyors are not explicitly named in the CDM 2007 Regulations as duty holders, they are therefore considered as being less conscious of their responsibility to promote H&S. This is demonstrated in the following quotations.

> *"Project quantity surveyor companies will always base their advice on cost of the last project…They'll not try to divide it into how much you put in for safety, quality, welfare, etc...So usually they're advising the client about, that's too expensive, don't buy that, buy this one, this is less expensive. Whereas, I believe, architects and engineers are much more conscious particularly with CDM, of their obligations, because they have obligations. Those obligations are less apparent to the cost advisors and therefore I don't think they give the same level of attention."* [Project Manager]

> *"My view at the moment is that clients do not fully appreciate that the programmes that they set are too tight. The problem is that they set it and people have to say that they'll work to it otherwise you're not going to win the job. And once you've said it you've got to stick to it otherwise you're going to get your LADs when you get to the end and you don't finish on time. In my view unrealistic programmes are a definite factor that increases risk. I don't think clients have fully understood that and I don't think clients have fully understood their responsibilities under the CDM regulations"* [H&S Manager]

Interviewees were also of the view that some designers are set in their ways when it comes to doing designs with intricate aesthetic qualities which impinge on buildability. It was acknowledged that although architecture should not be stifled, designers need to give thorough consideration of how the designs will physically be built and also about the maintainability of the facility when in-use.

> *"Architects and designers in some cases would say: that's the way the design is and so that's the way you'll build it. However, we can see problems with it…We try and point out these problems but some architects will say to you: that's my design, that's how I want it, and so that's how you build it- and that is a very difficult situation."* [H&S Manager]

### 7.1.3 How CPFs Influence Accident Occurrence

The project features were considered as being underlying accident causal factors with one interviewee even referring to them as, "*…something that sits behind everything…they are underlying and quite deep underlying root causes*". The analysis further revealed that the project features are associated with certain H&S issues which as a result make the project features have the potential to influence the occurrence of accidents. With regards to restriction of site locality which emerged from the interview, this was associated with difficulty in traffic (pedestrian and vehicle) control around the site vicinity. The H&S issues are given in Table 7.3 and they are site-based. A comparison of these H&S issues with those from literature (shown in Table 5.1) largely indicates congruence between the interviews and literature.

With the CPFs being considered to be *deep underlying root causes* with associated H&S issues which are site based, the interviews support one of the key elements in the conceptual model: that CPFs introduce into the construction phase proximate causes of accidents which give rise to accidents.

Table 7.3: CPFs and associated H&S issues

| **CPFs** | **Associated H&S issues** | **Comments on H&S issues associated with CPFs** |
|---|---|---|
| Nature of Project | Uncertainty of hazards | "It is true that in some sense refurbishment could be more dangerous because you wouldn't know if for instance there is asbestos in there…You could be working in a very old building with all kinds of things lurking there to catch you out." [H&S Manager]<br>"With new build obviously, you're starting from the ground but with refurbishment you are working blindly really. You don't know what is behind that plaster board, do you?" [Site Manager] |
| Method of Construction | Manual handling & Mechanical handling | "Obviously, the method of construction could influence the occurrence of accidents. As I said we try to keep man-handling down by using plants." [H&S Manager]<br>"For example the windows for this job arrived on site fully glazed… Lifting the windows by crane reduces manual handling risk but it introduces risk associated with operating a crane." [Site Manager] |
| Site Restriction | Congestion | "The separation of plant, workers, materials, and vehicles is more difficult on restricted site and so it's more dangerous to work on restricted sites." [Site Manager]<br>"If you get a tight site or where the foot print of your building takes the entire space of the site, where are you going to store materials, how are you going to get vehicles around?" [H&S Manager] |
| Project Duration | Time-pressure | "If the programme is very tight, definitely it has an impact because there may not be the time to do things the way you would ideally do them." [H&S Manager]<br>"When the duration is tight, the workers are under pressure and when they are under pressure they'll cut corners if you allow them. As soon as time-pressure is introduced accidents can occur."[Site Manager] |
| Procurement System | Fragmented project team (characterised by difficulty in collaborative working) | "I'll say some of the collaborative early contractor involvement type of procurement helps us to think through problems and things in more detail." [Civil Engineer & Director]<br>"It does pay dividend to be working with the design team months in advance before starting on site, and off-course through that you build a good relationship with the design team as well as some trust." [Project Manager] |
| Design Complexity | Difficulty in building (i.e. buildability) | "There were some quirks in the design. There were strange ceilings. We changed the design on that for a more practical solution." [Project Manager]<br>"I think one of the key issues is for designers to understand that it might look very good on paper but someone has to deliver the design in operational terms." [Construction H&S consultant] |
| Level of Construction | Working at height | "The level of construction could influence accident occurrence because of working at height. I feel more confident and everybody feels more confident the lower they are working." [Site manager] |
| Subcontracting | Fragmentation of workforce | "You give someone a contract and they give it to someone else and they give it to someone else to the point where people turn up on site and they don't know who they are working for because they are far down the chain." [Construction Manager]<br>"One of the big challenges for the industry is the subcontract culture… it is not unheard of for a team to turn up on site and they don't even know who we are because they've been contracted by somebody who has been contracted by somebody… So there is communication issue straight away." [H&S Manager] |
| Restriction of site locality | Difficulty in traffic (vehicle and pedestrian) control around | "When working in city centres you've got to be more aware of the public. For instance where we are now (i.e. Birmingham City Centre) there's about 10,000 people passing around every day. So that introduces some |

| CPFs | Associated H&S issues | Comments on H&S issues associated with CPFs |
|---|---|---|
| | site vicinity | risks.” [Project Manager]<br>“If you’re restricted or in a town centre itself, you’ve got to make sure that the public is safe at all times. You are looking after two jobs then. You are looking after the safety of the public and also the workforce. So it is easier to work away from the public or city centres or town centres.” [Site Manager]<br>“Inner city jobs are usually more dangerous with H&S because they are tight. There’s little of space. You have to time your deliveries, and getting stuff in and around the place.” [Project Manager] |

Concerning the conceptualised inter-causal relationships amongst project features and proximal factors, the interviews also showed evidence of such relationships. For instance, some interviewees were of the view that whilst design and build procurement does not guarantee improved buildability, it does offer the opportunity to improve buildability of designs due to contractor input in design, as follows:

> *"…Design and build gives you the opportunity to influence the design. I think the important thing with that is that a lot of construction companies may not actually realise they have that opportunity and so even if they don't have novated designers and they are their own designers, they might simply say we are not the designers, we'll subcontract the design, without realising they have the opportunity to think about the designs, to review designs and say well hang on a minute we'll never be able to build that or that's going to be difficult to build safely or expensive to build"*[H&S Manager]

Haslam *et al.* (2005) in their study similarly reported this perception about design and build. This means that design and build offers the opportunity to mitigate difficulty in construction associated with design complexity, and this provides an example of the possible inter-causal relations between CPFs and the proximate accident causes they introduce during the construction phase.

The interviews however did not provide any specific indication of possible interactions among the various site based H&S issues. Nonetheless from the interviewee's general acknowledgement of possible causal interactions in the occurrence of accidents, the possibility of causal interactions among the site based H&S issues cannot be discarded. The interviews thus also support the other key element of the conceptual model which is potential causal interactions between some CPFs and the proximal factors induced by other CPFs.

The interviews also revealed some measures implemented by the interviewee's companies to mitigate the accident causal influence of CPFs. A critical examination of the measures also gave some indication of how CPFs influence accident occurrence. For instance for a restricted site condition, some interviewees mentioned the need to do just-in-time delivery of materials to reduce congestion on site, and in the case of a restricted site locality the need to do night delivery to avoid or ease difficulty in traffic control around site vicinity. Speaking of design complexity, one interviewee mentioned the need to do a customised method of construction to cope with any difficulty in actual construction. These measures are aimed at addressing the H&S issues associated with the CPFs and are an acknowledgement of CPFs introducing some proximate causes of accidents into the construction phase. The measures also give hints of the hypothesised relationships between the degree of potential of a CPF to influence accident occurrence and the proximate accident cause(s) it introduces on site. This link can be seen as the measures are introduced to make the project environment created by the CPFs safe by mitigating the degree of potential of CPFs to influence accident occurrence through addressing the proximate accident causes they (i.e. CPFs) introduce.

### 7.1.4 Summary of the Qualitative Inquiry and Implications for the Quantitative Inquiry

In the pursuit of the wider research aim of investigating the accident causal influence of CPFs, this qualitative inquiry was undertaken with the objective of understanding *how* CPFs contribute to accident occurrence as a precursor to a quantitative study. The findings of the qualitative inquiry have further emphasised that the accident causal influence of CPFs as reported in the literature is undeniably existent. Pointing to restriction of site locality as another project feature with accident implications, the study has also shown that the occurrence of accidents on site through the causal influence of CPFs largely depends on the risk control measures put in place. This means that the existence of a ‘dangerous’ CPF on a project will not necessarily result in accidents as there may be effective risk control measures in place.

Regarding how CPFs influence accident occurrence, the findings lend support and credence to the key features of the conceptualised view of how CPFs contribute to accident occurrence. The conceptual model is thus a sound explanation of how CPFs influence accident occurrence. As accident causation models are useful in devising and implementing accident prevention measures, the conceptual model could similarly be useful.

The findings from the interviews have also given some indication that the hypothesised relationships highlighted in the measurement framework are well founded. As the measurement framework partly drew on the conceptual model, the verification of the model implies there is no need to modify the measurement framework. The next step is thus to implement the measurement framework to assess the potential of CPFs to influence accident occurrence and their associated H&S risk.

## 7.2 DEVELOPMENT OF THE QUANTITATIVE INQUIRY

As previously mentioned, quantitative research is a means of testing objective theories or prior formulations by examining the relationship among variables. It involves numerical and objective measurements to address questions relating to what, how much and how many (Fellows and Liu, 2008). The quantitative phase involved a systematic application of the measurement framework as follows:

1. assessing the degree of potential of CPFs to influence accident occurrence (including testing the proposed hypotheses) (i.e. facet 1); and
2. assessing the degree of H&S risk associated with CPFs by the use of a risk combination matrix to combine the assessed degree of potential of CPFs to influence accident occurrence with exposure (i.e. facet 2).

The data collection and analyses components of Facet 1 are presented in the following sections and the findings are presented in Chapter 8. Facet 2 is presented in Chapter 9.

### 7.2.1 Assessing the Degree of Potential of CPFs to Influence Accident Occurrence

From the literature review it was shown that the extant construction H&S literature only provides comparative assessment of the degree of potential of CPFs to influence accident occurrence (i.e. greater/lesser) without giving an indication of the degree of potential of individual CPFs to influence accident occurrence. This assessment is also confined to comparisons of CPFs of the same kind (e.g. comparing procurement systems). Bridging this gap means the need to objectively evaluate the degree of potential of CPFs to influence accident occurrence.

Construction accident causation studies have often involved analysis of accident records and representing the identified causes with frequencies (cf. Suraji *et al.*, 2001; Haslam *et al.*, 2005; Cooke and Lingard, 2011). In the case of this study, the acknowledgement by several researchers that investigating deep root causes (which are upstream of project procurement) using accident records poses difficulties (cf. Suraji *et al.*, 2001; Bomel Limited *et al.*, 2006; Cooke and Lingard, 2011) meant that accident records would not be appropriate in this study. This was confirmed through a preliminary enquiry made at the HSE regarding possible use of HSE accident records. In response to the enquiry, the HSE indicated that the CPFs being investigated are not recorded in accident records. The possible use of accident records in this study therefore seemed unlikely.

In order to get reliable data for assessing the degree of potential of CPFs to influence accidents, construction professionals were deemed a potential source of information, especially contractor personnel as they often witness and/or experience accidents on site. Contractor personnel (such as project managers, construction managers, H&S managers, and site managers), commonly work on project sites in management roles and also from their wide industrial experience in construction are likely to be aware of the CPFs being investigated and any influence they have on H&S. This was confirmed by the interviews. By drawing on their expertise and industrial experience, it was deemed that such professionals would be able to provide reliable information based on which a generic view of the degree of potential of CPFs to influence accident could be obtained and also the hypothesised relationships could be tested.

As previously mentioned, two common research strategies are used in quantitative research: experiment; and survey. In choosing between these it was resolved that experiments would not be ideal because they are usually carried out in a laboratory setting where the investigator can manipulate variables of interest directly, precisely and systematically (Yin, 2003). Survey, in particular a cross-sectional survey, was thus chosen, as the most appropriate strategy of inquiry as it provides a quantitative or numeric description of opinion of a population by studying a sample of that population. The use of survey thus meant it was possible to capture the opinions of contractor professionals (which are shaped by their knowledge and experience) regarding the accident causal influence of CPFs. Survey research involves the use of a questionnaire as an instrument to collect data and this approach has been used in many construction H&S studies (cf. Langford *et al.*, 2000; Kheni *et al.*, 2008; Frontline Consultants, 2011) and particularly in construction accident causation studies (cf. Whittington *et al.*, 1992). Hide (2003) for instance used a questionnaire in a construction accident causation study to investigate the extent to which several factors contribute to accident causation. All these studies demonstrate the suitability of a survey as an appropriate research strategy for the quantitative phase of this research.

#### 7.2.1.1 Unit of Analysis

The purpose of the quantitative phase was to assess the degree of potential of CPFs to influence accident occurrence, and their associated H&S risk. From this, the appropriate unit of analysis for the quantitative inquiry was the CPFs under investigation with the survey inquiring into their accident causal influence. Having resolved to use a survey, the quantitative phase was executed following five key steps: development of the survey instrument; pre-testing and revision of the survey instrument; sampling for main survey; administering the survey instrument; and analysis of the resulting data. These steps are discussed in the following sections.

#### 7.2.1.2 Questionnaire Development

Being the data collection tool, the questionnaire was designed to be ‘respondent-friendly’ in order to maximise the response rate, which is widely recognised as being particularly low in construction management research (Xiao, 2002). As proper questionnaire design is vital for successful data collection, considerable effort was directed towards doing this. As indicated earlier, the unit of analysis was the CPFs and in order to obtain reliable data to assess their degree of potential to influence accident occurrence and test the related research hypotheses, the views of contractor professionals regarding the accident causal influence of CPFs was required. As their perceptions are shaped by their expertise and industrial experience their responses can be can regarded as important, and a reasonable representation of the actual situation.

From the measurement framework and resulting hypotheses, three key variables needed to be measured:

- the degree of potential of CPFs to influence accident occurrence;
- the degree of potential of proximal factors to influence accident occurrence; and
- degree to which proximal factors are common within CPFs.

In order to gauge the expertise and experience of the contractor professionals which is important for the credibility of the research findings, information regarding expertise and experience of respondents also needed to be collected.

The questionnaire was designed in five parts. The first part requested background information relating to the professionals' expertise and experience. Professional role, years of professional experience in construction, construction related education, and professional membership are regarded as important indication of expertise and experience in construction (cf. Hallowell and Gambatese, 2009).

The second part of the questionnaire asked respondents to make a judgement as to the degree of potential of CPFs to influence accident occurrence. This was the dependent variable in the hypotheses testing. The CPFs comprised those which have been identified from literature as being persistently associated with accidents (as shown by Table 3.5) and also from the qualitative inquiry (i.e. Section 7.1.2). These are listed in Table 7.4 below. The degree of potential was assessed using a 5-point scale (0 = None, 1 = Low, 2 = Moderate, 3 = High, 4 = Very High). This scale is similar to that used by Hide (2003) in assessing the degree to which various factors generally contribute to accident causation in construction.

Table 7.4: List of CPFs

| **Construction Project Features** |
| --- |
| 1. Refurbishment |
| 2. Demolition |
| 3. New work |
| 4. Pre-assembly construction |
| 5. Traditional on-site construction |
| 6. A restricted site (i.e. where footprint of facility covers most of site area) |
| 7. An unrestricted site (i.e. where footprint of facility covers a small portion of the site area) |
| 8. A tight project duration |
| 9. An adequate project duration |
| 10. High-level construction (i.e. multi-level construction) |
| 11. Low-level construction (i.e. single-level construction) |
| 12. Underground construction |
| 13. Complex design (i.e. design with intricate aesthetic qualities) |
| 14. Simple design (i.e. design with simple aesthetic qualities) |
| 15. Multi-layer subcontracting |
| 16. Single-layer subcontracting |
| 17. Traditional method of procurement |
| 18. Design and build procurement |
| 19. Partnering procurement |
| 20. Management contracting |
| 21. Restricted site locality e.g. city centre location |
| 22. Unrestricted site locality e.g. outer city location |

The third part of the questionnaire asked respondents to make a judgement as to the degree of potential of proximal factors to influence accident occurrence. This was the moderator variable in the hypotheses testing. The proximal factors comprised those identified from the literature as being associated with the CPFs (as summarised by Table 5.1), and also from the qualitative inquiry (i.e. Section 7.1.3/Table 7.3). These are listed in Table 7.5 below. As with the second part, the degree of potential of proximal factors to influence accident occurrence was assessed using a 5-point scale (0 = None, 1 = Low, 2 = Moderate, 3 = High, 4 = Very High).

Table 7.5: Proximal factors associated with CPFs

| **Proximal Factors** |
|---|
| 1. Uncertainty of hazards |
| 2. Manual handling |
| 3. Housekeeping problems |
| 4. Time-pressure |
| 5. Site congestion |
| 6. Mechanical handling |
| 7. Fragmentation of project team |
| 8. Difficulty in constructing (i.e. buildability) |
| 9. Working at height |
| 10. Fragmentation of workforce |
| 11. Working in confined space |
| 12. Difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity |

The fourth part of the questionnaire asked the respondents to make a judgment regarding the extent to which proximal factors are generally common within their associated CPFs. This was the independent variable in the hypotheses testing. This was also assessed using a 5-point scale (0 = Not at all, 1 = Low, 2 = Moderate, 3 = High, 4 = Very High).

The final part of the questionnaire requested general information regarding accident causation, the accident causal influence of CPFs, and the respondents' interest in the research findings and further participation in the research. This was particularly useful in enriching the findings from the preceding parts of the questionnaire and also in validating the findings. Respondents who answered in the affirmative regarding further participation and/or receiving the research findings were subsequently asked to provide their contact details.

The various parts of the questionnaire were put together to constitute a 5 page survey instrument (see Appendix C-2). The cover page had a brief information about the aim of the research, the various sections in the questionnaire, approximate time to complete the questionnaire (i.e. 15 minutes), means of returning the completed questionnaire, and the researchers contact information. The questionnaire completion time was based on the average time three colleagues took to complete the questionnaire. The respondents were also told to provide responses based on their broad industrial experience and that there were no "correct" or "incorrect" answers. Once the questionnaire development was complete, it was ready for pre-testing.

#### 7.2.1.3 Pilot Survey

Pilot surveys are necessary to demonstrate the methodological rigor of a survey (Munn and Drever, 1995). A pilot was thus conducted to assess the clarity and comprehensiveness of the questionnaire, as well as the feasibility of the survey as a whole. In this regard an additional question was included in the last part of the questionnaire (i.e. general information section) requesting respondents to specify any questions or sections they had difficulty in understanding.

As previously discussed, the pilot survey targeted UK contractor personnel, especially those in construction management roles (e.g. H&S manager, project manager, construction manager and site manager). As there is no organised database for these professionals, it was considered that a viable means of reaching them would be through their employers' contacts (i.e. contractors). The survey was thus conducted on a sample of 50 contractors randomly drawn from the UK Kompass online directory. As a means of double-checking the contractors contact information, Google search engine (www.google.com) was used to search for contractors by name. The search revealed that some of the contractors were no longer in business; a situation which reflected the downturn in construction activity (cf. ONS, 2011). Those contractors were randomly replaced. A questionnaire was sent to each of the 50 contractors requesting for the participation of a professional in a construction management role. The questionnaires were administered by post (to 28 contractors) and by electronic means (to 22 contractors). Electronic questionnaires are particularly useful in minimising cost and also achieving quicker delivery. Electronic administration was used for the companies whose email contact were obtained from either the UK Kompass online directory or through the Google search. The electronic version of the questionnaire was in two forms: a fillable Acrobat portable document format (PDF); and also an online questionnaire hosted at eSurveyspro (www.esurveyspro.com). Respondents had the option to use either of the two. The pilot survey commenced from the 1st week of April 2011 and was closed in the 2nd Week of May 2011. It was interspersed with two reminders to the contractors sent at two weekly intervals.

#### 7.2.1.4 Results of Pilot Survey and Implications for Main Survey

The survey yielded 11 responses (i.e. 6 electronic questionnaires and 5 postal questionnaires) giving a response rate of 22%. This compares favourably with the 20% response rate achieved in the pilot survey reported in Ankrah (2007) and Xiao (2002). The respondents' roles were: construction manager (18.2%), health and safety manager (54.5%), and director (27.3%). Averagely, the respondents have 12.27 years of experience (with Std. Dev. = 6.798) and 24 years of experience (with Std. Dev. = 9.612) in their role and in construction respectively. The minimum and maximum experience in role is 4 years and 25 years respectively and that for experience in construction is 8 years and 35 years. A banded breakdown of the experience of the respondents (i.e. < 5 years, 5-10 years, 11-15 years, 16-20 years, and over 20 years) indicate that 90% of the respondents have at least 5 years of experience in their role and 90% have over 10 years of experience in construction. Approximately 80% of the respondents are members of at least one industrial professional body. The professional bodies and the grade of membership of the respondents are: Institution of Occupational Health and Safety (Technician member, Graduate member, Chartered Member), International Institution of Risk and Safety Management (Member), Institution of Civil Engineers (Associate Member, Member), and Chartered Institute of Building (Fellow). In terms of highest educational attainment, approximately 50% of the respondents have a Diploma or higher (i.e. Bachelors or Masters Degree). From the demographic data, the experience and expertise of the respondents is respectable and an indication that the respondents are capable of providing the information requested in the questionnaire. The little difference between the electronic response and postal response also suggested that both could yield similar response and as such either approach could be used with confidence.

7 out of the 11 respondents (i.e. 63.64%) showed willingness to participate in a further phase of the research and 9 out of 11 (i.e. 81.18%) showed willingness to receive the research findings. This is indication that the respondents are generally interested in the study and they consider it important. Of much importance, there was no indication from the respondents that any of the questions or parts of the questionnaire was difficult to understand. This demonstrated that the wording of the questions and the logical flow of the questionnaire was appropriate. It also demonstrated that the respondents were familiar with the terms used and the subject under investigation. Overall, the pilot survey indicated that the questionnaire was suitable to be administered in a larger survey. Parts of the pilot survey results have been published in Manu *et al.* (2012b).

#### 7.2.1.5 Sampling for Main Survey

As previously mentioned, contractor personnel in construction management roles (e.g. H&S manager, project manager, construction manager, and site manager) are the target source of data and hence constitute the population. Whilst the population should ideally be the total number of these construction professionals, practically this would be very difficult to define due to the unavailability of any record or database of these professionals. The unavailability of such database meant using contractors as a means of reaching the intended professionals. Contractors were thus used as the target population. It is on record that there are about 256,000 private UK contractors (ONS, 2011). As it will be impractical to collect data from all the contractors, sampling was necessary. As indicated in Babbie (1990), sampling is necessary because of the constraints of time and cost. It is important to emphasise that although contractors were sampled, the professionals in construction management roles within the companies were the ultimate target source of the data required.

Following the examples of Xiao (2002), Ankrah (2007), and Akadiri (2011), the sampling frame that was adopted for the selection of the sample was the list of contractors registered in the UK Kompass online register. In order to determine a suitable size for the sample, the following formula from Czaja and Blair (1996) and Creative Research Systems (2011) was applied:

$$ss = \frac{z^2 \text{ x } p\,(1 - p)}{c^2}$$

Where:

*ss* = sample size

*z* = standardised variable

*p* = percentage picking a choice, expressed as a decimal

*c* = confidence interval, expressed as a decimal

As with most other research, a confidence level of 95% was assumed (Munn and Drever, 1995; Creative Research Systems, 2011). For 95% confidence level (i.e. significance level of

$\alpha = 0.05$), $z = 1.96$. Based on the need to find a balance between the level of precision, resources available and usefulness of the findings (Maisel and Persell, 1996), a confidence interval ($c$) of ±10% was also assumed for this research. According to Czaja and Blair (1996), when determining the sample size for a given level of accuracy, the worst case percentage picking a choice ($p$) should be assumed. This is given as 50% or 0.5. Based on these assumptions, the sample size was computed as follows:

$$ss = \frac{1.96^2 \text{ x } 0.5(1 - 0.5)}{0.1^2}$$

$$ss = 96.04$$

Therefore the required sample size for the questionnaire survey is 96 contractors. However, this figure requires a further correction for finite populations. The formula for this is given in Czaja and Blair (1996) as:

$$new\ ss = \frac{ss}{1 + \frac{ss - 1}{pop}}$$

Where:

*pop* = population

The new sample size is therefore:

$$new\ ss = \frac{96.04}{1 + \frac{96.04 - 1}{256000}}$$

$$new\ ss = 96.\ 004$$

The sample size still remains approximately 96 contractors. The UK construction industry is well-known for poor response to questionnaire surveys. 20 – 30% is believed to be the norm (Takim *et al.*, 2004). For this reason it was necessary to adjust the sample size to account for non-response. Assuming a conservative response rate of 20%, the appropriate sample size to be surveyed was calculated as:

$$\text{survey } ss = \frac{new\ ss}{response\ rate}$$

$$\text{survey } ss = \frac{96.004}{0.2}$$

$$\text{survey } ss = 480\ contractors$$

In an effort to further improve the number of responses, this figure was doubled to 960 contractors and eventually approximated to a **1000 contractors**. A random selection of contractors from the UK Kompass online directory was thus made to provide a list of 1000 contractors by generating random numbers without replacement using Minitab statistical package. It is important to reiterate that although contractors were used as the target population, the individual practitioners in construction management roles (e.g. H&S manager, project manager, construction manager, and site manager) within the companies were the target source of data. The survey was thus aimed at soliciting individual practitioner views (regarding the accident causal influence of CPFs) with their companies only serving as a viable means of reaching the practitioners.

Once again, as a means of double-checking the contractors' contact information, Google search engine (www.google.com) was used to search for the contractors' contact by searching with the contractors' names. The search again revealed that some of the contractors were no longer in business or have changed their operating name. Those who were no longer in business were randomly replaced and for those operating with new names, their new names were used. It should be noted that although this was a laborious process, it was necessary in ensuring an adequate response, particularly given the difficulty in obtaining participation in H&S studies in the UK as previously mentioned (cf. Gibb *et al.*, 2002).

### 7.2.2 The Main Survey

The main survey was carried out from mid June 2011 to mid-August 2011. A total of 1000 questionnaires were administered. 580 were administered by post and 420 were administered electronically. Again those administered electronically were the companies for which an email address was obtained from the UK Kompass directory or through the Google search. For the postal questionnaire, a pack containing a cover letter (see Appendix C-1), a questionnaire, and a self-addressed free-post envelope was sent to each of the 580 contractors. The cover letter briefly introduced the research and its purpose and then requested for the participation of a professional in construction management role. For the electronically administered questionnaire, an email with an attached cover letter, and a questionnaire in fillable Acrobat PDF were sent to each of the 420 contractors. Included in the email was also a web link to an online version of the questionnaire hosted at eSurveyspro (www.esurveyspro.com). The participants again had the option to either complete the fillable Acrobat PDF questionnaire or the online version.

To help ensure a good response, the survey duration was interspersed with reminders. Although two follow-up remainders have been suggested to ensure high response rates (cf. Babbie, 1990; Creswell, 2009), resource limitations meant that only one reminder could be undertaken for the postal questionnaires. Like the first administration, a pack containing a reminder letter, a questionnaire, and a self-addressed free-post envelope was sent to each of the non-responding companies. This was done about four weeks after the first administration. With the electronic survey, 4 reminders were sent at approximately 2 weekly intervals with the first reminder being two weeks after the first administration. Again the reminder email comprised an attached cover letter and a questionnaire in fillable Acrobat PDF. A web link to the online version of the questionnaire was also included.

#### 7.2.2.1 Response Rate

By mid-August 2011 when the survey was closed a total of 187 questionnaires had been received out of the 1000 administered. The survey thus yielded a response rate of 18.7%. A breakdown of the response rate (given by Table 7.6) indicates that the postal survey yielded better response than the electronic survey, and thus suggesting that postal surveys are better than electronic surveys in terms of response rate.

Table 7.6: Response rate

| **Mode of questionnaire administration** | **Number of administered questionnaires** | **Number responses received** | **Response rate** |
|---|---|---|---|
| Electronic | 420 | 62 | 14.76% |
| Postal | 580 | 125 | 21.55% |
| Total | 1000 | 187 | 18.7% |

It is reported in Takim *et al.* (2004) that the response rate norm for questionnaire surveys is 20-30%. Other sources that support this view include Black *et al.* (2000) who reported a response rate of 26.7% for a questionnaire survey. Although the response rate of 18.7%

obtained in this survey is slightly lower compared with the response rate in these other sources, this should be weighed against the difficulty in obtaining participation in H&S studies in UK as previously mentioned. Given this difficulty, the obtained response rate is reasonable. Even lower response rates have been recorded in other UK based construction management surveys (e.g. 8.82% response reported by Sutrisna (2004)). Again, it should even be noted that in terms of the actual number of responses the 187 responses is approximately 195% of (i.e. about twice) the calculated sample size (i.e. 96).

#### 7.2.2.2 Data Screening

The responses from all 187 questionnaires were first input in Microsoft Excel 2003 to enable ease of data management and subsequent exporting to other statistical software packages. Missing data commonly occurs in research and it does occur for several reasons (Hair *et al.*, 2006). Missing data can be problematic and there is therefore the need to undertake missing data analysis in order to improve the validity of studies (LoPresti, 1998; Hair *et al.*, 2006). In order to have a good data set for the data analysis stage, the data was screened to assess the extent of missing data and to determine whether any remedial actions were required. The SPSS version 16 Missing Values Analysis option was used for the missing data analysis. The initial analysis revealed that 3 cases had excessive missing data (i.e. more the 50% of questions were unanswered). Following the recommendation by Hair *et al.* (2006), the 3 cases were removed. The effective sample size was thus 184 responses. Further analysis was undertaken following the exclusion of the 3 cases to reveal the missing data pattern (see Appendix D). Little's Missing Completely at Random (MCAR) Test which tests whether data is MCAR was not significant [*Chi-Square (df =1765) =1779.185, p = 0.42*] confirming that the missing data pattern is MCAR. Following the recommendations by Hair *et al.* (2006) the

Expectation-Maximisation method was used as the input method to replace metric missing values. The data was now ready for analysis.

### 7.2.3 The Quantitative Data Analyses Strategy

Referring to the quantitative phase of this research, an important aspect is the statistical data analyses undertaken on the collected survey data in order to achieve the research objective of assessing the degree of potential of CPFs to influence accident occurrence. The statistical analyses employed are presented in the following sections.

#### 7.2.3.1 Descriptive Statistics

In order to develop a thorough understanding of the nature of the data, several descriptive statistics including frequency distributions; measures of central tendency such as means, medians and modes; and measures of dispersion such as the standard deviation were employed. The descriptive statistics were undertaken using SPSS v16. The descriptive statistics were very important in demonstrating that the respondents were indeed the category of participants needed for the study and that their level of expertise and experience was suitable in according credence to their responses and hence the overall research findings. Again, given the need to have single representative assessments of the individual ratings by the respondents regarding the degree of potential of CPFs to influence accident occurrence (represented by "***C***"), the degree of potential of proximal factors to influence accident occurrence (represented by "***R***"), and the extent to which proximal factors are common within their respective CPFs (represented by "***r***"), aggregation of the individual ratings via mean calculation was important. The mean represents a summary of data (Field, 2005), and its use in aggregating individual ratings is consistent with its application in other similar construction accident causation studies. Hide (2003) for instance aggregated respondents' ratings on a 5-

point scale regarding the extent to which various factors contribute to accident causation by using mean calculation. In order for such mean values to be interpreted with confidence, there is also the need for evidence of agreement among the raters (i.e. respondents) (cf. Huang *et al.*, 2007; Anvuur and Kumaraswamy, 2010). Inter-rater agreement test was thus considered in this study.

### 7.2.3.2 Inter-rater Agreement Test

Inter-rater agreement represents the extent to which different judges/raters tend to make exactly the same judgments about the rated subject (Tinsley and Weiss, 1975). When judgments about a subject are made on a numerical scale, inter-rater agreement means that the judges assigned exactly the same values when rating the same subject. Inter-rater agreement estimates whether response from one judge/rater is “similar” to the responses of other judges/raters rating the same subject thus reflecting the degree of “sharedness” among the judges/raters. Inter-rater agreement is sometimes confused with inter-rater reliability which represents the extent to which the relationship between one rated individual to other rated individuals is the same, although the absolute numbers used to express this relationship may differ from judge to judge (Tinsley and Weiss, 1975). Inter-rater agreement test is often used in organisational multi-level research (Bliese, 2000) and it has been applied in construction management studies (cf. Tuuli, 2009; Anvuur and Kumaraswamy, 2010). In construction health and safety studies, inter-rater agreement test has also been applied (cf. Lingard et al., 2010). Two commonly used inter-rater agreement estimates are James *et al*. (1984) inter-rater agreement index ($r_{WG}$) and average deviation index by Burke *et al*. (1999). These are considered in more detail below.

### *Inter-rater Agreement Index*

James *et al*. (1984) proposed single item inter-rater agreement index ($r_{WG}$) and multiple-item scale inter-rater agreement index ($r_{WG(j)}$) for within group agreement in single-item and multiple-item situations respectively. James *et al*. (1984) initially labelled his estimates as within group inter-rater reliability indices and was subsequently criticised by Schmidt and Hunter (1989) on the basis that the indices were not consistent with the assumptions of classical measurement theory. Schmidt and Hunter (1989) suggested that if one proceeded to calculate an $r_{WG}$, then the ensuing estimate may have no meaningful interpretation. In support of James *et al*. (1984), Kozlowski and Hattrup (1992) indicated that the labelling of the indices was the source of confusion and suggested that the indices were rather appropriate for within-group inter-rater agreement. Agreeing with Kozlowski and Hattrup (1992), James *et al*. (1993) recast $r_{WG}$ as an estimate of inter-rater agreement.

There have been debates about the interpretation of the inter-rater agreement indices by James *et al.* (1984) in terms of what value represents an adequate level of agreement (Cohen *et al.*, 2001; Harvey and Hollander, 2004). The rule-of-thumb is that values greater than 0.70 demonstrate adequate agreement (Harvey and Hollander, 2004). This threshold has however been described as arbitrary and having no empirical foundation (Cohen *et al.*, 2001; Harvey and Hollander, 2004). Through Monte Carlo simulation Harvey and Hollander (2004) concluded that the widely used 0.70 rule of thumb produces a grossly inflated view of ratings quality across a wide range of rating situations and that adequate agreement should be judged using benchmarks that are appropriate to each rating situation. Brown and Hauenstein (2005) extended the 0.70 rule of thumb, proposing that values of 0 to 0.59 be considered as unacceptable agreement, 0.60 to 0.69 as weak agreement, 0.70 to 0.79 as moderate agreement, and 0.80 and above as strong agreement. Through simulations, Cohen *et al*. (2001) also found that $r_{WG}$ values vary considerably as a function of group size and number of items and thus implying that the conventional value of 0.70 may be a reasonable cut-off value for significant agreement with some configurations of group sizes and response items, but may not be reasonable for others. Cohen *et al*. (2001) therefore recommended that researchers simulate parameters based on the specific characteristics of the researchers' samples when determining $r_{WG}$ values of significant agreement.

### *Average Deviation Index*

As an alternative to the $r_{WG}$ index, Burke *et al*. (1999) proposed the average deviation index (AD). Average deviation is computed as the average of the absolute deviations of ratings from the mean ($AD_M$) or median ($AD_{Md}$). AD is therefore a measure of disagreement. Burke *et al*. (1999) indicated that average deviation index based on the median ($AD_{Md}$) is more sensitive to detecting agreement in comparison to average deviation based on the mean ($AD_M$). As argued by Burke *et al*. (1999), AD may provide a pragmatic index of agreement because it is a measure of variability interpretable in terms of the metric (units) of the original scale. Like the $r_{WG}$ index, the AD can be calculated for multiple-item scale.

There is debate over what levels of average deviation indicates adequate inter-rater agreement. Since AD indices actually measure disagreement, an AD of zero indicates there is perfect agreement among raters. Burke and Dunlop (2002) and subsequently Dunlop *et al*. (2003) provide critical values for evaluating the significance of the AD index at the 5% level of significance that tests the null hypothesis that there is no agreement among raters. They suggest that a criterion for acceptable inter-rater agreement or practical significance can be approximated as c/6, where c is the number of response options for a likert-type scale.

### 7.2.3.3 Choice of Inter-rater Agreement Index

The choice between $r_{WG}$ indices and AD indices for estimating inter-rater agreement has been a subject of debate (cf. Langfred, 2000; Dunlap *et al.*, 2003). In a recent review of organisational multi-level studies published between 2000 and 2006, Cohen *et al*. (2009) found that 93% of the studies that included justification of aggregation from individual-to-group level used the $r_{WG}$ index, 5% used the $AD_M$ and only one of the studies used both. Cohen *et al*. (2009) concluded that it is pre-mature to answer the question as to which of the two indices is more powerful for inferring agreement. In assessing inter-rater agreement in this study the single item inter-rater agreement index ($r_{WG}$) was used. The $r_{WG}$ indices were calculated using the R-Software Multi-level Package which is free under the terms of Free Software Foundation's GNU General Public License (obtainable from www.r-project.org). Following the recommendation by Cohen *et al*. (2001), the $r_{WG}$ values for significant agreement were estimated based on a sample size (i.e. group size) of 184 and a number of response items of 5 (i.e. the 5-point scale). $r_{WG}$ index has been used in construction management research including construction H&S studies (cf. Tuuli, 2009; Anvuur and Kumaraswamy, 2010; Lingard *et al.*, 2010).

### 7.2.3.4 Correlation and Regression

Two final statistical analyses applied were correlation and regression analysis to assess the existence of relationships between variables. These were used to test the hypothesised relationships between the degree of potential of a CPF to influence accident occurrence (i.e. *C)* and:

(1) the extent to which its proximal factor(s) is common within the CPF (i.e. *r*); and

(2) the potential of the proximal factor(s) to influence accident occurrence (i.e. *R*).

### *7.2.3.4.1 Correlation*

Pearson's correlation coefficient represented by '*r'*, was used. The equation to compute the correlation coefficient, *r*, is given by Field (2005) as:

$$r = \frac{\sum_{i=1}^{n} (x - \bar{x})(y - \bar{y})}{(n-1)S_x S_y}$$

Where:

$x$ and $y$ are any pair of variables whose level of correlation is being sought;

$\bar{x}$ and $\bar{y}$ are the means of $x$ and $y$ respectively;

$S_x$ and $S_y$ are the standard deviations of $x$ and $y$ respectively; and

n is the sample size.

The correlation coefficient lies between -1 and +1. A coefficient of +1 indicates that the two variables are perfectly positively correlated so that as one variable increases the other increases. Conversely, a coefficient of -1 indicates a perfect negative relationship so that as one variable increases, the other decreases. A coefficient of 0 indicates no linear relationship which means that if one variable changes the other variable stays the same. Correlation analysis is a very common statistical analysis used in construction management research including construction H&S studies (cf. Ankrah, 2007; Anvuur, 2008; Ikpe, 2009; Tuuli, 2009). The correlation analysis was conducted using SPSS v16.

### *7.2.3.4.2 Multiple Regression*

Multiple regression analysis is a statistical technique that can be used to analyse the relationship between a single dependent (criterion) variable and several independent (predictor) variables (Hair et al., 2010). It is a method for studying the effects and the magnitude of the effects of several independent variables on one dependent variable (Kerlinger and Lee, 2000). Where there is a single independent (predictor) variable, the regression analysis is called simple regression analysis (Hair et al., 2010). Multiple regression analysis leads to the derivation of an equation in which each independent (predictor) variable has its own coefficient and the dependent (outcome) variable is predicted from a combination of all the variables multiplied by their corresponding coefficients plus a residual term (Field, 2005). A generic equation for a multiple regression model is given in Field (2005) as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta n\, Xn + \varepsilon i$$

Where:

$Y$ is the outcome variable;

$\beta_0$ is the intercept/constant;

$\beta_1$ is the coefficient of the first predictor $X_1$;

$\beta_2$ is the coefficient of the second predictor $X_2$;

$\beta_n$ is the coefficient of the $n$th predictor $X_n$; *and*

$\varepsilon i$ is the difference between the predicted and observed value of Y for the $i$th subject.

In the case of a single independent variable (predictor) (i.e. simple regression) the generic regression equation is given by:

$$Y = \beta_0 + \beta X$$

Where:

$Y$ is the outcome variable;

$\beta_0$ is the intercept/constant; and

$\beta$ is the coefficient of the predictor $X$.

The coefficients are weights which effectively denote the relative contribution of the predictor variables to the overall prediction (Hair et al., 2010). The coefficients must however be statistically significant which means that they must significantly be different from zero (Hair et al., 2010). Aside using regression for prediction, it can also be used for explanation (Hair et al., 2010). Regression thus provides a means of objectively assessing the degree and nature of the relationship between dependent and independent variables by forming the variate of independent variables and then examining the magnitude, sign, and statistical significance of the regression coefficient for each independent variable (Hair et al., 2010). This is what makes regression analysis suitable for this research which seeks to verify hypothesised relationships. The regression analysis was conducted using SPSS v16.

The way independent variables are included in a regression model has an impact on the results obtained (Field, 2005). There are several methods of entry and these are hierarchical, forced entry, and stepwise methods (Field, 2005). In hierarchical entry, predictors are selected based on past work (Field, 2005). As a general rule-of-thumb, known predictors from past research are entered first in the order of their importance followed by new predictors. In forced entry, all the predictors are forced into the model simultaneously. As noted by Field (2005), this method also relies on the existence of sound theoretical basis for inclusion of all the chosen variables. In this research, the absence of strong empirical evidence of important predictors from the H&S literature meant that hierarchical entry was not suitable. The absence of a sound theoretical basis for simultaneous inclusion of all the variables in this study also meant that forced entry was not appropriate.

The most viable option for this research was thus the stepwise method. In the stepwise method, the decisions about what variables to enter into the model and the order in which they are entered are based entirely on a mathematical criterion (Field, 2005). In the stepwise method predictors not in the model are evaluated for entry one at a time, with the best predictor being entered into the model, and those already in the equation are evaluated for removal one at a time with the removal of the most insignificant predictor, until no more predictors are eligible for entry or removal (Field, 2005). The criterion for entry of a predictor is that the significance of the $F$ test must be $\leq 0.05$, and the criterion for removal is that the significance of the $F$ test must be $\geq 0.10$.

There are a number of assumptions associated with regression analysis. These assumptions must be met for the regression analysis to guarantee a model in which the actual errors in prediction are as a result of the real absence of a relationship among the variables and not caused by some characteristic of the data not accommodated by the regression procedure (Hair et al., 2010). These assumptions are given in Hair *et al*. (2010) as follows:

(1) Linearity of the phenomenon

(2) Constant variance of the error terms

(3) Independence of the error terms

(4) Normality of the error term distribution

The principal measure of prediction errors is the *residual*, which is the difference between the observed and predicted values for the outcome variable (Hair et al., 2010). Analysis of the residuals is thus the principal means of identifying violations of the assumptions. According to Hair *et al*. (2010), plotting residuals versus predictor and outcome variables is the basic method of identifying assumption violations. These assumptions are discussed in more detail below.

***Linearity of the phenomenon***

Regression assumes a linear relationship between the outcome variable and the predictor variables (Field, 2005; Hair *et al.*, 2010). The linearity of relationship between the dependent and independent variables represents the degree to which the change in the dependent variable is associated with the independent variable. Linearity can be assessed from an examination of residual plots which must show a random distribution of data points. Hair *et al.* (2010) and Field (2005) provide a number of residual plots which show non-linear patterns of residuals. Where such non-linear relationships exist, alternative regression methods such as the introduction of polynomial terms must be considered.

***Constant variance of the error terms***

The presence of unequal variances (i.e. heteroscedasticity) has been mentioned as one of the common assumption violations (cf. Hair et al., 2010). It is diagnosed by plotting studentised residuals against the predicted outcome values and comparing them to a null plot. A consistent pattern (triangle or diamond-shaped) in such a plot is evidence that the variance is not constant (Hair et al., 2010).

***Independence of the error terms***

For any two observations, the residual terms should be uncorrelated (i.e. independent) and this is sometimes described as the lack of auto-correlation (Field, 2005). This assumption can be tested with the Durbin-Watson test which tests for serial correlation between errors (Field, 2005). The test statistic can vary from between 0 and 4 with a value of 2 meaning that the residuals are uncorrelated. As a conservative rule of thumb, values between 1 and 3 are better (Field, 2005).

***Normality of the error term distribution***

It is assumed that the residuals in the regression model are random normally distributed variables. This assumption is considered to be the most frequently violated assumption (cf. Hair et al., 2010). The simplest diagnostic check for this assumption is the histogram of residuals which by visual inspection should be bell-shaped, approximating the normal distribution (Field, 2005). Another check is the use of the normal probability plot (P-P plot) which compares the standardised residuals with a normal distribution represented by a straight diagonal line. If the distribution is normal, then the residual line must closely lie on this diagonal line (Field, 2005; Hair *et al.*, 2010).

#### 7.2.3.5 Overview of Quantitative Data Analyses Strategy

Using the above data analysis techniques, the screened survey data was analysed. First, descriptive statistics were conducted on the respondents' background information to obtain the overall demographic information. Secondly, further descriptive statistics and inter-rater agreement tests were conducted on the responses regarding the degree of potential of CPFs to influence accident occurrence; the degree of potential of proximal factors to influence accident occurrence; and the extent to which proximal factors are common/prevalent within CPFs. This was followed by the test of the proposed hypotheses, and finally descriptive statistics and text analysis on the general comments provided by respondents. An outline of the entire data analyses with reference to the questionnaire is given by Figure 7.1.

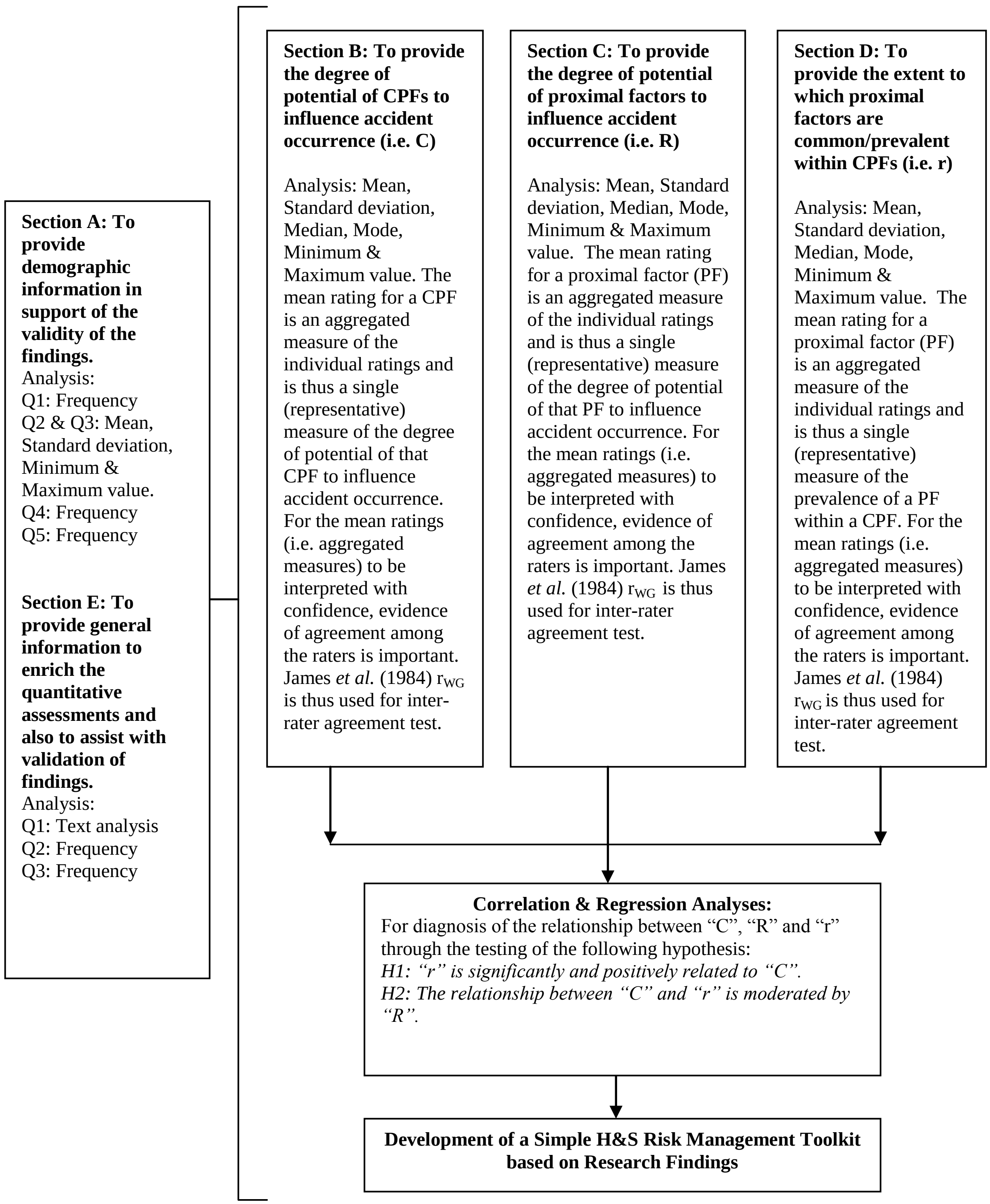



Figure 7.1: Outline of quantitative data analyses

## 7.3 SUMMARY

In the previous chapter, an overall sequential exploratory mixed method research design with an initial qualitative inquiry followed by a quantitative inquiry was adopted for the verification of the conceptual model and for the assessment of the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. The findings of the qualitative inquiry addressing the verification of the conceptual model have been presented in this chapter. The findings indicate that that the conceptual model is a sound depiction of how CPFs influence accident occurrence. Regarding how CPFs influence accident occurrence, the qualitative inquiry has thus shown that CPFs, originating from pre-construction decisions, introduce certain associated H&S issues (which can be termed as *proximal accident factors*) into the construction phase to give rise to accidents. In addition to this path of causation, the process by which CPFs influence accident occurrence could be marked by causal interactions between CPFs and proximal factors which could reduce or worsen the presence of the proximal factors they introduce. By this the qualitative inquiry has given evidence that the mechanism by which CPFs influence accident occurrence generally reflects the systems view of accident causation.

Progressing from the qualitative inquiry, the quantitative phase of the study addressing the implementation of the measurement framework was launched. The quantitative phase seeks to assess the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. As part of the quantitative phase, a survey instrument was developed, pre-tested and finally administered in a UK-wide survey. Altogether, out of a 1000 administered questionnaire, 187 responses (representing 18.7% response rate) were obtained. Following screening of the data, it was ready for analysis.

The following two chapters now present the results of statistical analyses undertaken on the screened data to assess the degree of potential of CPFs to influence accident occurrence and consequently their associated H&S risk.

# CHAPTER 8: QUANTITATIVE FINDINGS 1 - DEGREE OF POTENTIAL OF CONSTRUCTION PROJECT FEATURES TO INFLUENCE ACCIDENT OCCURENCE

## 8.0 INTRODUCTION

As previously mentioned, the survey elicited the perceptions of construction professionals regarding the accident causal influence of CPFs to enable an assessment of their degree of potential to influence accident occurrence. Based on the adopted research paradigm (i.e. positivism) the degree of potential of a CPF to influence accident occurrence (i.e. potential to cause accident/harm) is viewed as a single reality implying the need to aggregate the individual assessments of the respondents to have a single representative assessment. The following sections first present information on the expertise and experience of the respondents to demonstrate the credibility of their responses. The assessment of the degree of potential of CPFs to influence accident occurrence including the test of the related hypothesised relationships is subsequently presented. Finally, the results of the analysis of the general comments requested from the participants are presented. This chapter thus addresses part of the fourth research objective in terms of presenting the results of the data analysis in relation to the assessment of the degree of potential of CPFs to influence accident occurrence.

## 8.1 DEMOGRAPHIC INFORMATION

Tables 8.1 to 8.8 present the respondents' demographic information, the purpose of which is to provide an overview of the expertise and experience of the respondents so as to generate confidence and credibility in the research findings. Generally as shown by Table 8.1, most of the respondents (i.e. 82.02%) are project managers, construction managers, site managers and H&S managers. The roles of the remaining 17.94% of respondents which are given by Table

8.2 include: directors; engineers; contracts, operations, business improvement and technical managers; and quantity surveyors. From the remaining 17.94%, two participants (i.e. 9.9%) did not indicate their role. From Table 8.1 and 8.2, it is reasonable to combine some of the "other roles" in Table 8.2 with the pre-specified roles in Table 8.1 as some of the roles are closely related e.g. the roles relating to H&S. This yields Table 8.3 which indicates that a majority of the respondents (i.e. about 90%) are in direct construction management roles. The respondents are therefore largely the kind of participants who were targeted for the survey.

A summary of the respondents years of experience (shown by Table 8.4) indicates that averagely, the respondents have 16.30 years of experience (with Std. Dev. = 10.45) and 24.31 years of experience (with Std. Dev. = 11.97) in their role and in construction respectively. The minimum and maximum experience in role is 1 year and 62 years respectively and that for experience in construction is 2 years and 62 years. A banded breakdown of the experience of the respondents (i.e. <5 years, 5-10 years, 11-15 years, 16-20 years, and over 20 years) given by Table 8.5, indicates that 89.2% of the respondents have at least 5 years of experience in their role and 79.35% have over 10 years of experience in construction. This shows that a majority of the respondents are experienced in the management of construction and H&S and are also generally experienced in construction.

Table 8.1: Role of respondents

| **Role** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Project Manager | 14 | 7.61 |
| Construction Manager | 29 | 15.76 |
| Site Manager | 4 | 2.17 |
| H&S Manager | 104 | 56.52 |
| Other Role | 33 | 17.94 |
| Total | 184 | 100 |

Table 8.2: Details of other roles

| **Other Roles** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Quantity Surveyor | 2 | 6.06 |
| Construction and H&S Director | 1 | 3.03 |
| H&S Director | 1 | 3.03 |
| Senior Partner | 1 | 3.03 |
| Managing Director | 2 | 6.06 |
| Construction Director | 3 | 9.09 |
| Company Director | 1 | 3.03 |
| Integrated Manager (Health, safety, environment, and quality) | 1 | 3.03 |
| Director | 7 | 21.21 |
| Business Improvement Manager | 2 | 6.06 |
| Construction Engineer | 1 | 3.03 |
| Operations Manager | 1 | 3.03 |
| H&S Co-ordinator | 1 | 3.03 |
| Contracts Manager | 2 | 6.06 |
| Technical Manager | 1 | 3.03 |
| Safety Director and Consultant | 1 | 3.03 |
| Construction Manager & H&S Manager | 1 | 3.03 |
| Civil Engineer | 1 | 3.03 |
| Unspecified | 3 | 9.09 |
| Total | 33 | 100 |

Table 8.3: Combined role of respondents

| **Role** | **Frequency** | **Percentage (%)** | **Cumulative Percentage (%)** |
|---|---|---|---|
| Project/Operations/Contracts/Technical Manager | 18 | 9.78 | 9.78 |
| Construction Manager/Director/Engineer | 33 | 17.93 | 27.71 |
| Site Manager | 4 | 2.17 | 29.88 |
| H&S Manager/Director/Coordinator | 110 | 59.78 | 89.66 |
| Other Role | 19 | 10.33 | 100 |

Table 8.4: Summary of work experience of respondents

| **Statistic** | **Years of experience in role** | **Years of experience in construction industry** |
|---|---|---|
| Number of respondents | 184 | 184 |
| Mean | 16.30 | 24.31 |
| Std. Error of Mean | .770 | .88 |
| Std. Deviation | 10.45 | 11.97 |
| Minimum | 1 | 2 |
| Maximum | 62 | 62 |

Table 8.5: Banded breakdown of work experience of respondents

| **Experience in Role** | **Number of Respondents** | **Percentage (%)** | **Experience in Construction Industry** | **Number of Respondents** | **Percentage (%)** |
|---|---|---|---|---|---|
| <5 years | 20 | 10.87 | <5 years | 9 | 4.89 |
| 5-10 years | 45 | 24.46 | 5-10 years | 29 | 15.76 |
| 11-15 years | 41 | 22.28 | 11-15 years | 13 | 7.07 |
| 16-20 years | 27 | 14.67 | 16-20 years | 18 | 9.78 |
| >20 years | 51 | 27.72 | >20 years | 115 | 62.50 |
| Total | 184 | 100 | Total | 184 | 100 |

A summary of the respondents' professional membership (shown by Table 8.6) indicates that a majority of the respondents (i.e. 72.83%) have at least one professional affiliation. Details of the professional bodies and the range of the levels of membership of the respondents are given by Table 8.7. The bodies are mainly organisations which are associated with the management of construction and H&S matters and this reinforces the relevance of the respondents' expertise to the subject under investigation. In terms of education, the respondents' profile is given by Table 8.8. The highest educational qualifications of the respondents range from GCSE to PhD. For most of the respondents' (i.e. 19%) their highest educational qualification is a Bachelor's degree in a construction related discipline. Overall almost 50% of the respondents have a Diploma or higher qualification in a construction related discipline.

From the respondents' demographic information, it is evident that the experience and expertise of the respondents is respectable and they are well placed to adequately respond to the subject being addressed by the survey. Their responses can thus be regarded as important and reliable. A reasonable conclusion is that the findings drawn from their responses will be a sound and credible representation of the accident causal influence of CPFs.

Table 8.6: Membership of industrial professional body

| Membership | Number of Respondents | Percentage (%) |
|---|---|---|
| Member of at least 1 industrial professional body | 134 | 72.83 |
| No membership | 45 | 24.46 |
| Unspecified | 5 | 2.72 |
| Total | 184 | 100 |

Table 8.7: Professional bodies and grade/level of membership

| Professional Body | Range of Grade/Level of Membership of Respondents |
|---|---|
| Institution of Occupational Health and Safety | Affiliate member, Technician member, Graduate member, Incorporate member, Chartered member, Fellow |
| International Institution of Risk and Safety Management | Associate, Member, Graduate |
| Association of Professional Safety | Member |
| Institute of Environmental Management & Assessment | Affiliate, Associate, Member |
| Institution of Civil Engineers | Graduate, Associate Member, Member, Fellow |
| Institute of Risk Management | Chartered member |
| Royal Institute of Chartered Surveyors | Associate, Member |
| Chartered Institute of Building | Student member, Technician, Associate, Member, Fellow |
| Chartered Quality Institute | Associate |
| Society for the Environment | Chartered environmentalist |
| Institution of Materials, Minerals and Mining | Member |
| Institute of Construction Management | Member |
| Institute of Directors | Member |
| Chartered Institute of Management | Member |
| Institution of Engineers- Ireland | Unspecified |
| Chartered Institute of Personnel and Development | Associate member |
| Institute of Leadership & Management | Member |
| The Institution of Royal Engineers | Member, Fellow |
| Royal Society of Public Health | Fellow |

Table 8.8: Education

| Highest Level of Education | Number of Respondents | Percentage (%) |
|---|---|---|
| GCSE | 8 | 4.0 |
| O-Level | 11 | 6.0 |
| A- Level | 9 | 5.0 |
| NVQ/SVQ/City & Guilds | 17 | 9.0 |
| ONC/HNC/Some Certificate Course | 30 | 16.0 |
| HND/Some Diploma Course | 33 | 18.0 |
| Bachelors Degree | 35 | 19.0 |
| Postgraduate Cert./Postgraduate Dip./Masters Degree | 18 | 10.0 |
| PhD | 1 | 1.0 |
| Unspecified | 22 | 12.0 |
| Total | 184 | 100 |

## 8.2 ASSESSMENT OF THE DEGREE OF POTENTIAL OF CPFs TO INFLUENCE ACCIDENT OCCURRENCE

Table 8.9 indicates a summary of the assessment of the degree of potential of the CPFs to influence accident occurrence. For each of the CPFs the ratings by the respondents ranged from 0 (no potential to influence accident occurrence) to 4 (i.e. very high potential to influence accident occurrence). The aggregated ratings by the individual respondents (i.e. mean ratings) indicate that demolition has the greatest degree of potential to influence accident occurrence with a mean rating of 3.17 (with Std. Dev. = .9537). Pre-assembly construction is viewed as having the least degree of potential to influence accident occurrence with a mean rating of 1.51 (with Std. Dev. = .7763).

From Table 8.9, the standard deviations are relatively small compared to the mean ratings and this indicates that there is little variability in the data. This can also be seen from the mode and median values which are generally the same and the fact that the mean ratings are also approximately the same as the median and mode values. These generally mean that the mean ratings are a good fit of the data (Field, 2005). The standard error is the standard deviation of sample means and is a measure of how well a sample represents a population (Field, 2005). A large standard error (relative to the sample mean) suggests that there is a lot of variability between means of different samples. A small standard error suggests that most sample means are similar to the population mean and so the sample is likely to be an accurate reflection of the population (Field, 2005). The standard error values associated with all the means are relatively close to zero suggesting that the sample chosen is an accurate reflection of the population.

In order for all the mean ratings to be interpreted with much confidence, evidence of agreement amongst the respondents is important. As previously mentioned, agreement test was conducted using the single-item inter-rater agreement index ($r_{WG}$) by James *et al.* (1984). Such tests demonstrate the degree of consensus or "sharedness" among raters of the same subject. The presence of significant agreement means that the aggregated (i.e. mean) ratings can be considered as being credible representations of the respondents' individual assessments of the degree of potential of the CPFs to influence accident occurrence. The calculated $r_{WG}$ value for each CPF is indicated in Table 8.9.

Conventionally, $r_{WG}$ values $\geq 0.70$ is considered as evidence of significant agreement. Cohen *et al*. (2001) however found that $r_{WG}$ values vary considerably as a function of group size and number of response items and thus implying that the conventional value of 0.70 may be a reasonable cut-off value for significant agreement with some configurations of group sizes and number of response items, but may not be reasonable for others. Therefore, following the recommendation by Cohen *et al*. (2001), the $r_{WG}$ values for significant agreement were thus estimated based on a sample size (i.e. group size) of 184 and a number of response items of 5 (i.e. the 5-point scale). Based on 10,000 simulation runs, $r_{WG}$ values of 0.08, 0.10 and 0.14 are the 90%, 95% and 99% confidence interval estimates respectively for group size of 184 and 5 response options. $r_{WG}$ values > 0.14 are thus evidence of significant agreement at $p < 0.01$. From Table 8.9, it is evident that all the $r_{WG}$ values for the CPFs exceed 0.14. This means that there is significant agreement amongst the respondents as to the degree of potential of each of the CPF to influence accident occurrence. The mean ratings are therefore credible representations of the respondents' assessments and can be interpreted with confidence.

When the mean ratings are rounded to the nearest point on the 5-point scale to ensure conformity with the scale so as to aid interpretation, the eventual overall assessment indicated by Table 8.10 shows that the CPFs are generally perceived as having a *moderate* or *high* potential to influence accident occurrence. In other words, the CPFs are viewed as either having a *fair* potential to cause harm or a *severe* potential to cause harm in terms of the H&S of workers. Unlike the previous assessment in literature (see Table 5.2 of Section 5), this overall assessment is not just a comparison between CPFs of the same kind (e.g. comparing design and build procurement with management contracting) in terms of their degree of potential to influence accident occurrence. The assessment enables relative comparison among all the CPFs as it provides the individual degree of potential of each of the CPFs to influence accident occurrence. The assessment reveals both expected and surprising results and these are discussed below.

### 8.2.1 Discussion

From the overall assessment given by Table 8.10, none of the CPFs is generally perceived as not having the potential to influence accident occurrence. This confirms the evidence in the extant literature and the findings of the qualitative inquiry that indeed the CPFs have the potential to influence accident occurrence. The overall assessment of a *moderate* or a *high* potential to influence accident occurrence, also confirms that indeed the CPFs have varying potential to influence accident occurrence.

Regarding nature of project, as indicated by Table 8.10, demolition and refurbishment are generally perceived as having a *high* potential to influence accident occurrence whereas new work is generally perceived as having a *moderate* potential.

Table 8.9: Descriptive statistics and inter-rater agreement indices for degree of potential of CPFs to influence accident occurrence

| **Construction Project Feature** | ***Mean** | **Std. Error** | **Std. Deviation** | **Median** | **Mode** | **Minimum** | **Maximum** | **$^{**}r_{WG}$** |
|---|---|---|---|---|---|---|---|---|
| Demolition | 3.1739 | .07031 | .95367 | 3.00 | 4.00 | 0.00 | 4.00 | 0.55 |
| Underground construction | 2.8368 | .06611 | .89677 | 3.00 | 3.00 | 0.00 | 4.00 | 0.60 |
| Tight project duration | 2.8361 | .05200 | .70531 | 3.00 | 3.00 | 0.00 | 4.00 | 0.75 |
| High-level construction | 2.7554 | .06585 | .89319 | 3.00 | 3.00 | 0.00 | 4.00 | 0.60 |
| Multi-layer subcontracting | 2.6998 | .05780 | .78400 | 3.00 | 3.00 | 0.00 | 4.00 | 0.69 |
| Complex design | 2.6141 | .06252 | .84802 | 3.00 | 3.00 | 0.00 | 4.00 | 0.64 |
| Restricted site | 2.6089 | .05962 | .80872 | 3.00 | 3.00 | 0.00 | 4.00 | 0.67 |
| Restricted site locality | 2.5703 | .05625 | .76306 | 3.00 | 3.00 | 0.00 | 4.00 | 0.71 |
| Refurbishment | 2.5169 | .06808 | .92349 | 3.00 | 3.00 | 0.00 | 4.00 | 0.57 |
| Traditional on-site construction | 2.2174 | .04853 | .65830 | 2.00 | 2.00 | 0.00 | 4.00 | 0.78 |
| New work | 1.9858 | .05537 | .75112 | 2.00 | 2.00 | 0.00 | 4.00 | 0.72 |
| Management contracting | 1.9499 | .05613 | .76143 | 2.00 | 2.00 | 0.00 | 4.00 | 0.71 |
| Design and build procurement | 1.8260 | .05728 | .77698 | 2.00 | 2.00 | 0.00 | 4.00 | 0.70 |
| Traditional method of procurement | 1.8058 | .05972 | .81008 | 2.00 | 2.00 | 0.00 | 4.00 | 0.67 |
| Unrestricted site locality | 1.7955 | .05496 | .74548 | 2.00 | 2.00 | 0.00 | 4.00 | 0.72 |
| Unrestricted site | 1.7949 | .05814 | .78860 | 2.00 | 2.00 | 0.00 | 4.00 | 0.69 |
| Partnering procurement | 1.7709 | .05604 | .76016 | 2.00 | 2.00 | 0.00 | 4.00 | 0.71 |
| Low-level construction | 1.7111 | .05441 | .73799 | 2.00 | 2.00 | 0.00 | 4.00 | 0.73 |
| Adequate project duration | 1.6558 | .05376 | .72922 | 2.00 | 2.00 | 0.00 | 4.00 | 0.60 |
| Single-layer subcontracting | 1.6252 | .05360 | .72704 | 2.00 | 2.00 | 0.00 | 4.00 | 0.74 |
| Simple design | 1.5475 | .05433 | .73703 | 1.00 | 1.00 | 0.00 | 3.00 | 0.73 |
| Pre-assembly construction | 1.5146 | .05723 | .77634 | 1.00 | 1.00 | 0.00 | 4.00 | 0.70 |

* Mean ratings are based on a 5 point scale (0 = none, 1= low, 2= moderate, 3 = high, 4 = very high).
**$r_{WG}$ = Single-item inter-rater agreement index. $r_{WG}$ indices are based on a uniform null distribution. Based on 10,000 simulation runs, $r_{WG}$ values of 0.08, 0.10 and 0.14 are the 90%, 95% & 99% confidence interval estimates respectively for group size of 184 and 5 response options (i.e. 5 point scale). Hence $r_{WG}$ values > 0.14 are evidence of significant agreement at $p < 0.01$.

Table 8.10: Overall degree of potential of CPFs to influence accident occurrence (approximated to nearest point on scale)

| **Construction Project Features** | **Mean degree of potential** | **Degree of Potential to influence accident occurrence** | |
|---|---|---|---|
| | | **High (3)** | **Moderate (2)** |
| Demolition | 3.1739 | ✓ | |
| Underground construction | 2.8368 | ✓ | |
| Tight project duration | 2.8361 | ✓ | |
| High-level construction | 2.7554 | ✓ | |
| Multi-layer subcontracting | 2.6998 | ✓ | |
| Complex design | 2.6141 | ✓ | |
| Restricted site | 2.6089 | ✓ | |
| Restricted site locality | 2.5703 | ✓ | |
| Refurbishment | 2.5169 | ✓ | |
| Traditional on-site construction | 2.2174 | | ✓ |
| New work | 1.9858 | | ✓ |
| Management contracting | 1.9499 | | ✓ |
| Design and build procurement | 1.8260 | | ✓ |
| Traditional method of procurement | 1.8058 | | ✓ |
| Unrestricted site locality | 1.7955 | | ✓ |
| Unrestricted site | 1.7949 | | ✓ |
| Partnering procurement | 1.7709 | | ✓ |
| Low-level construction | 1.7111 | | ✓ |
| Adequate project duration | 1.6558 | | ✓ |
| Single-layer subcontracting | 1.6252 | | ✓ |
| Simple design | 1.5475 | | ✓ |
| Pre-assembly construction | 1.5146 | | ✓ |

This is not surprising as it is consistent with literature (cf. Egbu, 1999; Anumba *et al.*, 2006; Hughes and Ferrett, 2008; HSE, 2009a). This was also acknowledged by interviewees (in the qualitative inquiry), one of whom expressed that:

> *"Refurbishment projects, compared to new builds are more prone to accidents…This is a green field project…I'll say refurbishment project is more prone to incidents than new builds like this project. However you still have to monitor health and safety."* [Project Manager]

Again from Table 8.10, tight project duration being generally perceived as having greater potential to influence accident occurrence than adequate project duration is also not surprising (cf. Mayhew *et al.*, 1997; Hide *et al.*, 2003; Brace *et al.*, 2009). This comparative assessment reflects the interview findings where it was opined by some interviewees that clients set tight time-scales without recognising that those tight durations have accident implications.

Conforming to literature (cf. Hide *et al.*, 2003; Brace *et al.*, 2009) and the interview findings, Table 8.10 shows that complex design is generally perceived as having greater potential to influence accident occurrence than simple design. As intimated by one interviewee in the qualitative inquiry:

> *"We are looking at a 100m high control tower at XYZ[1] airport at the minute and the designer has done this (i.e. an-hour glass shape). So how are you supposed to get to the outside and build that in glass cladding or whatever it is. So that design itself is problematic with the potential for incidents. Somebody could fall off or something"* [Project Manager]

Regarding level of construction it is not surprising that high level construction and underground construction are generally perceived as having greater potential to influence accident occurrence than low level construction (cf. Chua and Goh, 2005). From Table 8.9,

[1] *XYZ is the name of an airport*

underground construction has a mean rating of 2.84 (with Std. Dev. = 0.8968) right behind demolition (which has the highest mean rating), confirming its direness.

Given reports in studies such as those conducted by Mayhew and Quinlan (1997), Hide *et al.* (2003), Ankrah (2007), and Brace *et al.* (2009) it is also unsurprising that whereas multi-layer subcontracting is generally perceived as having a *high* potential to influence accident occurrence, single-layer subcontracting is perceived as having a *moderate* potential to influence accident occurrence. Multi-layer subcontracting being perceived as having greater potential to influence accident occurrence than single-layer subcontracting also reflects the views of the interviewees in the qualitative inquiry where an interviewee for instance expressed that:

> *"With sub-sub-subcontracting, you give someone a contract and they give it to someone else and they give it to someone else to the point where people turn up on site and they don't know who they are working for because they are far down the chain. That's kind of scary"* [Construction Manager]

Concerning restriction of site, the overall assessment given by Table 8.10 is also consistent with the comparative assessment given in literature (see Table 5.2 of Section 5). The overall assessment of restricted site locality having a *high* potential to influence accident occurrence compared to unrestricted site locality having a *moderate* potential to influence accident occurrence (shown in Table 8.10) converges with the views held by interviewees in the qualitative inquiry. As intimated by one interviewee:

> *"...Inner city jobs are usually more dangerous with H&S because they are very tight"* [Project Manager].

The overall assessment given by Table 8.10 also reveals some intriguing findings. For instance the procurement methods are all considered as having similar potential to influence accident occurrence (i.e. *moderate potential*) despite reports in literature which suggests that design and build and partnering improve H&S as they allow for collaborative working among project team members and hence fostering H&S management (cf. Matthews and Rowlinson, 1999; Brabazon *et al.*, 2000; Hide *et al.*, 2003). This also contradicts views by the interviewees in the qualitative inquiry that collaborative procurement methods offer better health and safety outcomes. Among comments which reflect this view is:

> *"From a health and safety point of view, design and build project is better than traditional procurement."* [Project Manager]

The expectation therefore was that traditional procurement and management contracting would be perceived as having a greater potential to influence accident occurrence than design and build procurement and partnering. In contrast to this, all the procurement methods are all generally perceived as having a *moderate* potential. A plausible reason for this is that, team fragmentation which has been mentioned to be unfavourable to H&S management (Brabazon *et al.*, 2000) is still evident even among the collaborative procurement methods. Baiden *et al*. (2006) for instance reported that on a project which was procured through design and build there was still evidence of lack of team integration. Another plausible reason for this surprising finding is that given the calls for team integration in construction (cf. Latham, 1994; Egan, 1998) even projects procured through traditional procurement may now be exhibiting improvement in team integration. This can be seen from studies such as the study by Ankrah (2007) who reported that even on projects that are procured through the traditional procurement approach contractors are being involved in the design, which is a sign of greater collaboration. This was also confirmed at the qualitative inquiry stage by one of the interviewees who mentioned that:

> *"This project is a traditional contract. It is a traditional one so you'd normally do exactly what's on the drawings you receive from the architect. With design and build, you design and then build it yourself. Fortunately, we worked with the design team for approximately 6 months before we started the project...They (i.e. the designer) have said it was a great move getting us involved early in the project and in fact they said maybe they should have gotten us involved sooner... It does pay dividend to be working with the design team months in advance before starting on site. And off-course through that you build a good relationship with the design team as well and some trust"* [Project Manager]

Given the unverified hypothesised relationship between the degree of potential of a CPF to influence accident occurrence and the extent to which its proximal factor(s) is common within it, it is pre-mature to firmly conclude that the various procurement methods are generally considered as having a similar moderate degree of potential to influence accident occurrence as a result of there being similar degrees of team fragmentation within them. The test of hypotheses could thus be useful in understanding this surprising finding.

Another surprising finding is that despite the reported H&S benefits of pre-assembly construction (cf. Wright *et al.*, 2003; McKay, 2010), it is generally perceived as having a similar potential to influence accident occurrence (i.e. *moderate* potential) just as traditional method of construction. This also contradicts views by the interviewees in the qualitative inquiry that pre-assembly is better than traditional method of construction in terms of achieving good H&S outcomes. Among comments which reflect this view are:

> *"The more that can be done off-site the less the risk. I've done modular student accommodation where everything comes fitted out in a complete box and you stack one box on top of another. It's a very quick operation and very safe."* [Project Manager]

> *"Prefabrication definitely has the opportunity to reduce accidents on site. Where they do the prefabrication, they would be able to do it in a more controlled environment than on a construction site. A very good example of pre-fabrication is installing*

> *services in risers. We built the new ABC*[2] *in London and that involved lots of services-some huge risers. The traditional way of doing that would be to scaffold the risers and get guys to fit in pipes, and duct works which meant lots of risks, lots of falls...Prefabrication, great, brilliant. The more of that, the better."* [H&S Manager]

The expectation therefore was that traditional construction would generally be assessed as having greater potential (perhaps at least a high potential) than pre-assembly construction. A plausible reason for this surprising result is that perhaps manual handling, the extent of which has been suggested to be related to the degree of potential of traditional construction to influence accident occurrence may be becoming safer within the industry. That is just to suggest that perhaps safer manual handling techniques are being introduced and practised within the industry. Again given the lack of empirical evidence as to the practice of safer manual handling techniques and also the absence of empirical evidence as to the relationship between the degree of potential of a CPF to influence accident occurrence and the degree of potential of its proximal factor(s) to influence accident occurrence, no firm explanation can be given. Once again, it may be possible to obtain some explanation from the hypotheses testing.

In the main, despite the emergence of unexpected findings, the overall assessment given by Table 8.10 largely converges with literature and the findings from the qualitative inquiry in terms of the comparative degree of potential of CPFs to influence accident occurrence (i.e. a CPF having greater or lesser potential than another). The unexpected findings however require further probing and in that regard the hypotheses testing could be beneficial. Despite the emergence of both expected and unexpected findings, a new perspective provided by the results is the individual assessments of the degree of potential to influence accident occurrence accorded to each CPF (i.e. *moderate* or *high* referenced to a 5-point scale). Going a step

[2] *ABC is the name of a hospital*

beyond the limited comparative assessment given in literature, the overall assessment provided by Table 8.10 allows for comparison across all CPFs. Committing resources for mitigating the potential of CPFs to influence accident occurrence can thus be based on the overall generic assessment offered by Table 8.10.

## 8.3 ASSESSMENT OF THE DEGREE OF POTENTIAL OF PROXIMAL FACTORS TO INFLUENCE ACCIDENT OCCURRENCE

Table 8.11 indicates a summary of the assessment of the degree of potential of the proximal factors to influence accident occurrence. Similar to the assessment of the degree of potential of CPFs to influence accident occurrence, the proximal factors as given in Table 8.11 have been listed together to give an overview of how they compare with each other in terms of their degree of potential to influence accident occurrence (i.e. their potential to cause accident/harm). From the mean ratings it is evident that uncertainty of hazards has the greatest degree of potential to influence accident occurrence with a mean rating of 3.11 (with Std. Dev. = .0589). Mechanical handling is viewed as having the least degree of potential to influence accident occurrence with a mean rating of 1.96 (with Std. Dev. = .0571). All the standard deviations are relatively small compared to the mean ratings thus indicating little variability in the data. Again this can also be seen from the mode and median values which are generally the same and the fact that the mean ratings are approximately the same as the median and mode values. The mean ratings are therefore a good fit of the data (Field, 2005). The standard errors associated with all the mean ratings are relatively close to zero and again suggests that the sample chosen is an accurate reflection of the population.

In order for all the mean ratings to be interpreted with much confidence, evidence of agreement amongst the respondents is important. The calculated single-item inter-rater agreement index ($r_{WG}$) for each proximal factor (i.e. single item) is also indicated in Table 8.11. From Table 8.11, it is evident that all the $r_{WG}$ values for the proximal factors exceed 0.14 which is the $r_{WG}$ value for significant agreement at $p < 0.01$ for group size of 184 and response items of 5. This means that there is significant agreement amongst the respondents as to the degree of potential of each of the proximal factors to influence accident occurrence. The mean ratings are therefore credible representations of the respondents' assessments and can be interpreted with confidence.

When the mean ratings are rounded to the nearest point on the 5-point scale to ensure conformity with the scale so as to aid interpretation, the eventual overall assessment indicated by Table 8.12 shows that the proximal factors are generally perceived as having a *moderate* or *high* potential to influence accident occurrence. In order words, the proximal factors are generally considered as either having a *fair* potential to cause harm or a *severe* potential to cause harm in terms of the H&S of workers. With the exception of fragmentation of project team, fragmentation of workforce, manual handling and mechanical handling which are generally perceived as having *moderate* potential to influence accident occurrence, all the other proximal factors are generally considered to have a *high* potential to influence accident occurrence.

### 8.3.1 Discussion

From the overall assessment given by Table 8.12, none of the proximal factors is generally perceived as not having the potential to influence accident occurrence. This confirms that the proximal factors do influence accident occurrence as reported in the H&S literature.

Table 8.11: Descriptive statistics and inter-rater agreement indices for potential of proximal factors to influence accident occurrence

| **Proximal Factor** | ***Mean** | **Std. Error** | **Std. Deviation** | **Median** | **Mode** | **Minimum** | **Maximum** | ****$r_{WG}$** |
|---|---|---|---|---|---|---|---|---|
| Uncertainty of hazards | 3.1141 | .05885 | .79823 | 3.00 | 3.00 | 0.00 | 4.00 | 0.68 |
| Working at height | 2.9076 | .05753 | .78032 | 3.00 | 3.00 | 0.00 | 4.00 | 0.70 |
| Site congestion | 2.8913 | .04930 | .66868 | 3.00 | 3.00 | 1.00 | 4.00 | 0.78 |
| Time-pressure | 2.8750 | .05287 | .71718 | 3.00 | 3.00 | 0.00 | 4.00 | 0.74 |
| Difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity | 2.8261 | .05516 | .74817 | 3.00 | 3.00 | 1.00 | 4.00 | 0.72 |
| Working in confined space | 2.6881 | .06523 | .88476 | 3.00 | 3.00 | 0.00 | 4.00 | 0.61 |
| Difficulty in constructing (i.e. buildability) | 2.6522 | .05657 | .76729 | 3.00 | 3.00 | 1.00 | 4.00 | 0.71 |
| Housekeeping problems | 2.5888 | .05404 | .73299 | 3.00 | 3.00 | 1.00 | 4.00 | 0.73 |
| Fragmentation of workforce | 2.4825 | .05455 | .74001 | 2.00 | 2.00 | 1.00 | 4.00 | 0.73 |
| Fragmentation of project team | 2.4022 | .05510 | .74745 | 2.00 | 2.00 | 0.00 | 4.00 | 0.72 |
| Manual handling | 2.2306 | .05568 | .75532 | 2.00 | 2.00 | 0.00 | 4.00 | 0.71 |
| Mechanical handling | 1.9565 | .05707 | .77408 | 2.00 | 2.00 | 0.00 | 4.00 | 0.70 |

* Mean ratings are based on a 5 point scale (0 = none, 1= low, 2= moderate, 3 = high, 4 = very high).
**$r_{WG}$ = Single-item inter-rater agreement index. $r_{WG}$ indices are based on a uniform null distribution. Based on 10,000 simulation runs, $r_{WG}$ values of 0.08, 0.10 and 0.14 are the 90%, 95% & 99% confidence interval estimates respectively for group size of 184 and 5 response options (i.e. 5 point scale). Hence $r_{WG}$ values > 0.14 are evidence of significant agreement at $p < 0.01$.

Table 8.12: Overall degree of potential of proximal factors to influence accident occurrence (approximated to nearest point on scale)

| **Proximal Factors** | **Mean** | **Degree of Potential to influence accident occurrence** | |
|---|---|---|---|
| | | **High (3)** | **Moderate (2)** |
| Uncertainty of hazards | 3.1141 | ✓ | |
| Working at height | 2.9076 | ✓ | |
| Site congestion | 2.8913 | ✓ | |
| Time-pressure | 2.8750 | ✓ | |
| Difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity | 2.8261 | ✓ | |
| Working in confined space | 2.6881 | ✓ | |
| Difficulty in constructing (i.e. buildability) | 2.6522 | ✓ | |
| Housekeeping problems | 2.5888 | ✓ | |
| Fragmentation of workforce | 2.4825 | | ✓ |
| Fragmentation of project team | 2.4022 | | ✓ |
| Manual handling | 2.2306 | | ✓ |
| Mechanical handling | 1.9565 | | ✓ |

From Table 8.12, it is unsurprising that most of the proximal factors are generally perceived as having a *high* potential to influence accident occurrence given their persistent association with accidents and their adverse outcomes such as injuries and illnesses (cf. Hide *et al.*, 2003; HSE, 2009a; Brace *et al.*, 2009; HSE, 2011a). With uncertainty of hazards, workers are prone to being harmed by hazards such as asbestos and electricity and hence the need for measures such as asbestos surveys. Under the CDM 2007, the requirement for clients to provide pre-construction information and also the requirement to produce a H&S file are hugely important as they provide a means of informing the construction team about any concealed hazards. Working at height has also persistently been a major cause of fatal accidents and hence The Work at Height Regulations 2005 and guidance such INDG401 (rev1) (HSE, 2007c) and that prepared by Cameron *et al*. (2005) on fall protection for the HSE. Working at height accounts for fall injuries which usually are approximately 50% of fatal injuries in construction almost every year (HSE, 2009a). It is thus unsurprising that working at height is generally assessed as having a *high* potential to influence accident occurrence.

As noted by Hide *et al.* (2003), congested site conditions imply insufficient working space, constricted room for vehicle manoeuvrability and difficult access to drop-off points, possibly resulting in the need for double handling of materials, all of which have safety implications. Congested site conditions could thus result in a worker being struck by a moving vehicle or object which are among the common kinds of fatal accidents in construction (HSE, 2009a). It is therefore not surprising that site congestion is generally perceived as having a *high* potential to influence accident occurrence. As acknowledged in literature (cf. Hide *et al.*, 2003), time-pressure is inimical to H&S as in such situations workers tend to place greater priority over productivity than H&S. The tendency for workers to cut corners and side-step H&S

procedures is great when there is time-pressure. This was also confirmed by the qualitative inquiry. For instance, in a narrated case of a fall accident, the interviewee mentioned that it was influenced by poor workmanship and time-pressure. An extract from the narration is given below:

> *"If he had put the supporting blocks below the knots, the lath would have been stronger and he wouldn't have fallen through. So again you can question the workmanship. But why had he done these given that he had 40 years experience? Why had he taken so many short-cuts? In the end what it came down to was that he was a couple of days behind the roofing schedule and so to get the job done quicker, he took some short-cuts."* [H&S Manager]

The overall assessment of time-pressure as having a *high* potential to influence accident occurrence is thus a reflection of reports in literature and comments expressed in the qualitative inquiry.

Although the HSE accident statistics make no direct mention of causes of accident such as difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity and housekeeping problems, the number of injuries to members of general public (which can be associated with difficulty in traffic control around site vicinity) (cf. HSE, 2011a) and the number of slips and trips injuries on site (which can be associated with poor housekeeping) (HSE, 2009a) give some indication of the direness of these proximal factors. In the construction industry, there have been 20 fatal injuries and over 900 non-fatal injuries to members of public from 2005/2006 to 2009/2010 (HSE, 2011a). The HSE (2009a) also indicates that slips, trips and fall on same level are a major kind of accident which has accounted for over 9600 major injuries from 1996/1997 to 2007/2008. The overall degree of potential to influence accident occurrence accorded to difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity and housekeeping problems is thus a reasonable reflection of these statistics.

Working in confined space and difficulty in constructing (i.e. buildability) are also among the proximal factors which are generally perceived as having a *high* potential to influence accident occurrence. This assessment reflects the seriousness to address these causes of accidents which is evident in the existence of regulations such as the Confined Spaces Regulations 1997 and the CDM 2007 regulations. Under the Confined Spaces Regulations 1997, entry to confined spaces should be avoided but where unavoidable, a safe system of work should be followed and adequate emergency arrangements should also be put in place before the work starts. Under the CDM 2007, designers, among other things, are also required to take buildability of designs into consideration. The existence of regulatory measures such as these shows the seriousness attached to addressing these proximal factors and by extension reflects their *high* potential to influence accident occurrence.

Fragmentation of workforce which is marked by differences in safety practices, competence, and interest in H&S amongst the workforce; difficulty in communication amongst the workforce; unclear working relationships; and ambiguity about H&S responsibility, clearly undermines on-site H&S management (cf. Mayhew and Quinlan, 1997; Hide *et al.*, 2003) and has accidents implications. Likewise, fragmentation of the project team which is marked by difficulty in collaborative working/less collaboration amongst project members is also noted to impact on H&S (cf. Mayhew and Quinlan, 1997; Matthews and Rowlinson, 1999; Brabazon *et al.*, 2000; Hide *et al.*, 2003). The requirement for cooperation among participants involved on a project under the CDM 2007 also reinforces the significance of working together to achieve good H&S outcomes. In view of these one would expect that fragmentation of workforce and fragmentation of the project team will generally be assessed as having at least a *high* potential to influence accident occurrence just as the proximal factors discussed above. Nonetheless, these two proximal factors being generally assessed as having a *moderate* potential (and not *low*) is still recognition of the seriousness of their degree of harmfulness in terms of H&S.

Surprisingly, manual handling is generally perceived as having a *moderate* potential to influence accident occurrence as mechanical handling. The HSE (2009a) indicates that *manual handling* is involved in one-third of all construction accidents in the UK and Perttula *et al.* (2003) in Finland, also attributed manual handling to a third of the accidents in their study. The expectation therefore was that manual handling would generally be assessed as having a greater potential (perhaps a *high* potential). As previously alluded to, this perception of manual handling may be due to the introduction and practice of safer manual handling techniques in the industry. Although mechanical handling is more likely to be better controlled as plant and equipment are used, it still has the potential to cause harm (Hughes and Ferrett, 2008) and therefore it being perceived as having *moderate* potential to influence accident occurrence is reasonable.

In summary, the overall assessment of the potential of proximal factors to influence accident occurrence is a reasonable reflection of what pertains in the construction industry as indicated by previous reports and industry H&S statistics. Although the overall assessment of the degree of potential of CPFs to influence accident occurrence is of greater importance in this study as it addresses one of the research questions, the overall assessment of the potential of the proximal factors to influence accident occurrence is also of value as it enables meaningful interpretation of the mean ratings of the potential of the proximal factors to influence accident occurrence (given in Table 8.11). Through such interpretation it is realised that the mean ratings are a sound indication of what actually pertains in industry and as such any further analysis incorporating the means ratings will yield credible findings.

## 8.4 ASSESSMENT OF THE EXTENT TO WHICH PROXIMAL FACTORS ARE COMMON/PREVALENT WITHIN CPFs

Table 8.13 indicates a summary of the assessment of the degree to which proximal factors are common (in other words prevalent) within their respective CPFs. The assessment shows that the extent to which working at height is common within high level construction is the greatest with a mean rating of 3.183 (with Std. Dev. = .8508). The perceived least extent to which a proximal factor is common within its CPF is the extent to which difficulty in constructing is common within simple design (mean rating = 1.4367; Std. Dev. = 0.6551). As with the preceding assessments, the standard deviations are all relatively small compared to the mean ratings and this indicates that the mean ratings are a good fit of the data (Field, 2005). Again the standard error values points that the sample chosen is an accurate reflection of the population.

Once again, given the need for evidence of significant agreement amongst the respondents' in order for the mean ratings to be interpreted with much confidence, single-item inter-rater agreement indices ($r_{WG}$) were calculated as given in Table 8.13. From Table 8.13 it is evident that all the $r_{WG}$ values exceed 0.14 which is the $r_{WG}$ value for significant agreement at $p < 0.01$ for group size of 184 and response items of 5. This means that there is significant agreement amongst the respondents as to the extent to which the proximal factors are common/prevalent within their respective CPFs. Again, the mean ratings are therefore credible representations of the respondents' assessments and can be interpreted with confidence.

Table 8.13: Descriptive statistics and inter-rater agreement indices for extent to which proximal factor is common/prevalent within CPF

| **Extent to which proximal factor is common/prevalent within CPF** | ***Mean** | **Std. Error** | **Std. Dev.** | **Medn.** | **Mode** | **Min.** | **Max.** | ****$r_{WG}$** |
|---|---|---|---|---|---|---|---|---|
| Uncertainty of hazards within Refurbishment | 2.7714 | .06902 | .93629 | 3.00 | 3.00 | .00 | 4.00 | 0.56 |
| Uncertainty of hazards within Demolition | 2.9324 | .06989 | .94803 | 3.00 | 3.00 | .00 | 4.00 | 0.55 |
| Uncertainty of hazards within New work | 1.6246 | .05424 | .73580 | 2.00 | 1.00 | .00 | 4.00 | 0.73 |
| Working at height within High-level construction | 3.1832 | .06272 | .85076 | 3.00 | 3.00 | .00 | 4.00 | 0.64 |
| Working at height within Low-level construction | 1.9756 | .06611 | .89674 | 2.00 | 2.00 | .00 | 4.00 | 0.60 |
| Fragmentation of workforce within Single-layer subcontracting | 1.7728 | .05373 | .72886 | 2.00 | 2.00 | .00 | 4.00 | 0.73 |
| Fragmentation of workforce within Multi-layer subcontracting | 2.7273 | .05915 | .80241 | 3.00 | 3.00 | .00 | 4.00 | 0.68 |
| Fragmentation of project team within Traditional procurement | 1.8553 | .05479 | .74317 | 2.00 | 2.00 | .00 | 4.00 | 0.72 |
| Fragmentation of project team within Design and Build procurement | 1.8109 | .05393 | .73153 | 2.00 | 2.00 | .00 | 4.00 | 0.73 |
| Fragmentation of project team within Partnering procurement | 1.8198 | .05738 | .77830 | 2.00 | 2.00 | .00 | 4.00 | 0.70 |
| Fragmentation of project team within Management contracting | 2.0225 | .05212 | .70703 | 2.00 | 2.00 | .00 | 4.00 | 0.75 |
| Manual handling within Pre-assembly construction | 1.7465 | .05678 | .77017 | 2.00 | 2.00 | .00 | 4.00 | 0.70 |
| Manual handling within Traditional construction | 2.6614 | .05142 | .69753 | 3.00 | 3.00 | 1.00 | 4.00 | 0.76 |
| Mechanical handling within Pre-assembly construction | 2.4021 | .06770 | .91827 | 3.00 | 3.00 | .00 | 4.00 | 0.58 |
| Mechanical handling within Traditional construction | 2.3238 | .05338 | .72411 | 2.00 | 2.00 | 1.00 | 4.00 | 0.74 |
| Housekeeping problems within Pre-assembly construction | 1.6178 | .05919 | .80288 | 1.5498 | 1.00 | .00 | 4.00 | 0.68 |
| Housekeeping problems within Traditional construction | 2.6827 | .05331 | .72318 | 3.00 | 3.00 | .00 | 4.00 | 0.74 |
| Time-pressure within Tight project duration | 3.1322 | .05001 | .67841 | 3.00 | 3.00 | 1.00 | 4.00 | 0.77 |
| Time-pressure within Adequate project duration | 1.7843 | .05251 | .71232 | 2.00 | 2.00 | .00 | 4.00 | 0.75 |
| Working in confined space within Underground construction | 2.9240 | .06446 | .87436 | 3.00 | 3.00 | .00 | 4.00 | 0.62 |
| Site congestion within Restricted site | 3.0472 | .05299 | .71876 | 3.00 | 3.00 | 1.00 | 4.00 | 0.74 |
| Site congestion within Unrestricted site | 1.5992 | .05076 | .68854 | 2.00 | 2.00 | .00 | 4.00 | 0.76 |
| Difficulty in constructing within Complex design | 2.8957 | .05655 | .76707 | 3.00 | 3.00 | .00 | 4.00 | 0.70 |
| Difficulty in constructing within Simple design | 1.4367 | .04830 | .65512 | 1.00 | 1.00 | .00 | 3.00 | 0.79 |
| Difficulty in traffic control around site vicinity within Restricted site locality | 3.0732 | .05151 | .69869 | 3.00 | 3.00 | 1.00 | 4.00 | 0.76 |
| Difficulty in traffic control around site vicinity within Unrestricted site locality | 1.6104 | .05537 | .75104 | 2.00 | 1.00 | .00 | 4.00 | 0.72 |

* Mean ratings are based on a 5 point scale (0 = none, 1= low, 2= moderate, 3 = high, 4= very high).
**$r_{WG}$ = Single-item inter-rater agreement index. $r_{WG}$ indices are based on a uniform null distribution. Based on 10,000 simulation runs, $r_{WG}$ values of 0.08, 0.10 and 0.14 are the 90%, 95% & 99% confidence interval estimates respectively for group size of 184 and 5 response options (i.e. 5 point scale). Hence $r_{WG}$ values > 0.14 are evidence of significant agreement at $p < 0.01$.

Table 8.14: Overall degree to which proximal factor is common/prevalent within CPF (approximated to nearest point on scale)

| Item | Mean | Degree to which Proximal Factor is Common within CPF | | |
|---|---|---|---|---|
| | | **High (3)** | **Moderate (2)** | **Low (1)** |
| Uncertainty of hazards within Refurbishment | 2.7714 | ✓ | | |
| Uncertainty of hazards within Demolition | 2.9324 | ✓ | | |
| Uncertainty of hazards within New work | 1.6246 | | ✓ | |
| Working at height within High-level construction | 3.1832 | ✓ | | |
| Working at height within Low-level construction | 1.9756 | | ✓ | |
| Fragmentation of workforce within Single-layer subcontracting | 1.7728 | | ✓ | |
| Fragmentation of workforce within Multi-layer subcontracting | 2.7273 | ✓ | | |
| Fragmentation of project team within Traditional procurement | 1.8553 | | ✓ | |
| Fragmentation of project team within Design and Build procurement | 1.8109 | | ✓ | |
| Fragmentation of project team within Partnering procurement | 1.8198 | | ✓ | |
| Fragmentation of project team within Management contracting | 2.0225 | | ✓ | |
| Manual handling within Pre-assembly construction | 1.7465 | | ✓ | |
| Manual handling within Traditional construction | 2.6614 | ✓ | | |
| Mechanical handling within Pre-assembly construction | 2.4021 | | ✓ | |
| Mechanical handling within Traditional construction | 2.3238 | | ✓ | |
| Housekeeping problems within Pre-assembly construction | 1.6178 | | ✓ | |
| Housekeeping problems within Traditional construction | 2.6827 | ✓ | | |
| Time-pressure within Tight project duration | 3.1322 | ✓ | | |
| Time-pressure within Adequate project duration | 1.7843 | | ✓ | |
| Working in confined space within Underground construction | 2.9240 | ✓ | | |
| Site congestion within Restricted site | 3.0472 | ✓ | | |
| Site congestion within Unrestricted site | 1.5992 | | ✓ | |
| Difficulty in constructing within Complex design | 2.8957 | ✓ | | |
| Difficulty in constructing within Simple design | 1.4367 | | | ✓ |
| Difficulty in traffic control around site vicinity within Restricted site locality | 3.0732 | ✓ | | |
| Difficulty in traffic control around site vicinity within Unrestricted site locality | 1.6104 | | ✓ | |

As was previously done, when the mean ratings are rounded to the nearest point on the 5-point scale to ensure conformity with the scale so as to aid interpretation, the eventual overall assessment indicated by Table 8.14 shows that generally the extent to which the proximal factors are common within their CPFs is generally considered as being *low*, *moderate* or *high*. In other words, the extent to which the proximal factors are common within their CPFs is generally considered as either being slight, fair or severe.

### 8.4.1 Discussion

From the overall assessment, none of the proximal factors is generally considered as not being common/prevalent within their respective CPFs. This confirms the evidence in the literature and the findings of the qualitative inquiry that indeed the proximal factors are associated with their respective CPFs. The variability in the overall assessment (i.e. *low, moderate, and high*) also confirms that the extent to which proximal factors are common/prevalent within CPFs varies.

Generally the overall assessment (given in Table 8.14) is consistent with literature in terms of the comparative degree to which proximal factors are common within their associated CPFs (as given by Table 5.2 of Chapter 5). For instance, uncertainty of hazards is generally considered to be more common/prevalent within demolition and refurbishment (i.e. *high*) than within new work (i.e. *moderate*) (Egbu, 1999; Anumba *et al.*, 2006). Similarly the comparative extent to which working at height, fragmentation of workforce, manual handling, housekeeping problems, time-pressure, site congestion, difficulty in constructing, and difficulty in traffic control around site vicinity, are common within their respective CPFs conform with the comparative assessments given in literature as summarised by Table 5.2.

Table 8.14 however indicates some surprising findings. Firstly fragmentation of project team is generally perceived as being *moderate* within all the procurement systems in contradiction to reports that design and build and partnering offer greater team integration (cf. Matthews and Rowlinson, 1999; Brabazon *et al*., 2000; Baiden, 2006; Eriksson, 2010). The expectation therefore was that traditional procurement and management contracting would generally be considered as having greater fragmentation of project team within them (perhaps at least *high*) than design and build and partnering (perhaps *low* or at worst *moderate*). Fragmentation of project team being perceived as being similar (i.e. *moderate*) within all the procurement systems gives credence to the suggestion that the real cultural change from adversarial relationships to collaborative relationships heralded by approaches like partnering is not being fully embraced (Bresnen and Marshall, 2000; Sullivan, 2006) and that very often these new procurement methods are approached as a "tick in the box" exercise (Sullivan, 2006). Similar to the inference made by Ankrah *et al.* (2009), it can also be inferred from this result that it should not be taken for granted that simply adopting a particular procurement method would automatically result in enhanced team collaboration. Although some procurement methods may give the opportunity for better team integration, project participants still need to work at changing the adversarial culture through training and development in aspects such as teamwork (Nicolini, 2002; Rowlinson and Cheung, 2004). As alluded to previously regarding the similar degree of potential of the procurement methods to influence accident occurrence (i.e. moderate), this assessment could be due to the similar degree (i.e. moderate), to which fragmentation of workforce is common/prevalent within the procurement methods.

Another surprising finding is the extent to which mechanical handling is perceived to be common within pre-assembly construction and traditional on-site construction. From Table

8.14, the extent to which mechanical handling is common within pre-assembly construction is generally perceived as being moderate just as the extent to which mechanical handling is common within traditional on-site construction. Traditionally due to the need to install heavy components which are pre-fabricated off-site, pre-assembly is noted to involve greater mechanical handling than traditional on-site construction (cf. Wright et al., 2003). The expectation therefore was that mechanical handling would in overall terms be assessed as being more common within pre-assembly construction than within traditional on-site construction. A plausible reason for this contradiction is that perhaps with increasing technologies in construction, traditional on-site construction techniques are incorporating more mechanical means of handling for in-situ construction.

In summary, the overall assessment of the extent to which proximal factors are common within their associated CPFs is a sound snapshot of what pertains in industry given that generally the assessment is congruent with literature. Thus any further analysis involving the mean ratings is likely to yield trustworthy findings.

## 8.5 TEST OF HYPOTHESES

In Chapter 5 the following hypotheses were proposed:

*H1: The degree to which a proximal factor(s) is common/prevalent within a CPF will be significantly and positively related to the degree of potential of the CPF to influence accident occurrence.*

*H2: The relationship between the degree to which a proximal factor(s) is common/prevalent within a CPF and the degree of potential of the CPF to influence accident occurrence will be moderated by the potential of the proximal factor(s) to* *influence accident occurrence such that the relationship becomes more positive as the potential of the proximal factor(s) to influence accident occurrence becomes more positive.*

In testing these hypotheses the outcome variable (i.e. the degree of potential of a CPF to influence accident occurrence, represented by "*C"*), independent variable (i.e. the degree of prevalence of proximal factor(s) within a CPF, represented by "*r*"), and the moderator variable (i.e. the degree of potential of proximal factor(s) to influence accident occurrence, represented by "*R*") were organised and entered into SPSS v16 for correlation analysis. Bivariate correlations among the variables are given by Table 8.15.

Table 8.15: Pearson's correlation matrix

| | Degree of potential of CPF to influence accident occurrence (C) | Prevalence of PF(s) within CPF (r) | Degree of potential of PF(s) to influence accident occurrence (R) |
|---|---|---|---|
| Degree of potential of CPF to influence accident occurrence (C) | 1.000 | .924** | .408* |
| Prevalence of PF(s) within CPF (r) | .924** | 1.000 | .267 |
| Degree of potential of PF(s) to influence accident occurrence (R) | .408* | .267 | 1.000 |

** Correlation is significant at the 0.01 level (1-tailed). * Correlation is significant at the 0.05 level (1-tailed).

The correlation matrix indicates that there is significant correlation among all the variables except the correlation between the degree of potential of PF(s) to influence accident occurrence and the degree of prevalence of PF(s) within CPF (r = 0.267). This means that there is no association between the degree of potential of PF(s) to influence accident occurrence and the degree of prevalence of PF(s) within CPF. This outcome provides evidence of the independence of the predictor variable and moderator variable which is one of the requirements for reliable regression analysis. The degree of prevalence of PF(s) within CPF is significantly and positively related to the degree of potential of CPF to influence accident occurrence (r = 0.924, $p < 0.01$). This means that higher degree of prevalence of PF(s) within CPF is associated with higher degree of potential of CPF to influence accident occurrence. The degree of potential of PF(s) to influence accident occurrence is significantly and positively related to the degree of potential of CPF to influence accident occurrence (r = .408, $p < 0.05$). This means that higher degree of potential of PF(s) to influence accident occurrence is associated with higher degree of potential of CPF to influence accident occurrence. Whilst none of the relationships exposed in the correlation matrix confirm causality *per se* (Field, 2005), they may be indicative of underlying linear causal relationships and as such require further exploration. It can therefore be inferred from the results that there is sufficient evidence of linear relationships to proceed with the regression analysis to test the above hypothesised relationships.

### 8.5.1 The Influence of Degree of Prevalence of Proximal Factor(s) within CPF on the Degree of Potential of CPF to Influence Accident Occurrence

Hypothesis H1 posits that degree of prevalence of a proximal factor(s) within a CPF will be significantly and positively related to the degree of potential of the CPF to influence accident occurrence. To test this hypothesis, regression analysis was applied with degree of potential of CPF to influence accident occurrence as the outcome variable, and degree of prevalence of proximal factor(s) within CPF as the independent variable. The output of the regression analysis is given in Table 8.16. From Table 8.16, the value of $R^2$ for the model generated is .854, implying that prevalence of proximal factor within CPF accounts for 85% of the variation in potential of CPF to influence accident occurrence. The analysis of variance

(ANOVA) which tests whether or not the model is a useful predictor of potential of CPF to influence accident occurrence, gives a highly significant result ($F = 117.122$, $p < .001$), indicating that this model significantly improves the prediction of potential of CPF to influence accident occurrence. Again the t-test for the ß-value of prevalence of proximal factor(s) within CPF ($t=9.810$, $p < 0.001$) is strong evidence that prevalence of proximal factor(s) within CPF significantly predicts the degree of potential of CPF to influence accident occurrence.

Table 8.16: Regression analysis for the influence of prevalence of proximal factor(s) within CPF on the degree of potential of CPF to influence accident occurrence

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R | .924 | $R^2$ | .854 | Adjusted $R^2$ | .847 | | |
| Std. Error | .2011 | $R^2$ Change | .854 | Durbin-Watson | 1.264 | | |
| Analysis of variance | df | Sum of Squares | Mean Square | F | Sig. | | |
| Regression | 1 | 4.740 | 4.740 | 117.122 | .000 | | |
| Residual | 20 | .809 | .040 | | | | |
| Total | 21 | 5.549 | | | | | |
| Variables in equation | B | Std. Error | Beta | t | Sig. | Tolerance | VIF |
| (Constant) | .402 | .169 | | 2.374 | .028 | | |
| Prevalence of proximal factor(s) within CPF | .773 | .071 | .924 | 10.822 | .000 | 1.000 | 1.000 |

The ß-value being positive also indicates a positive relationship. Should the model be used for prediction, the ß-value tells the extent to which prevalence of proximal factor(s) within CPF affects the degree of potential of CPF to influence accident occurrence. However the focus of the hypothesis test is to verify and explain relationship. To test the assumptions of the regression, an analysis of residuals was undertaken. Plots of the residuals are shown in Figures 8.1, 8.2 and 8.3.

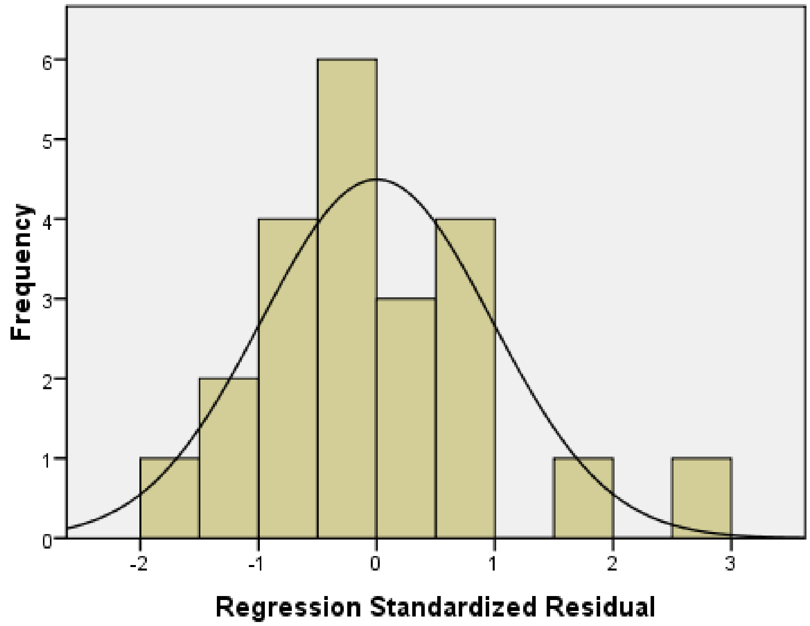



Figure 8.1: Histogram of standardised residuals- H1

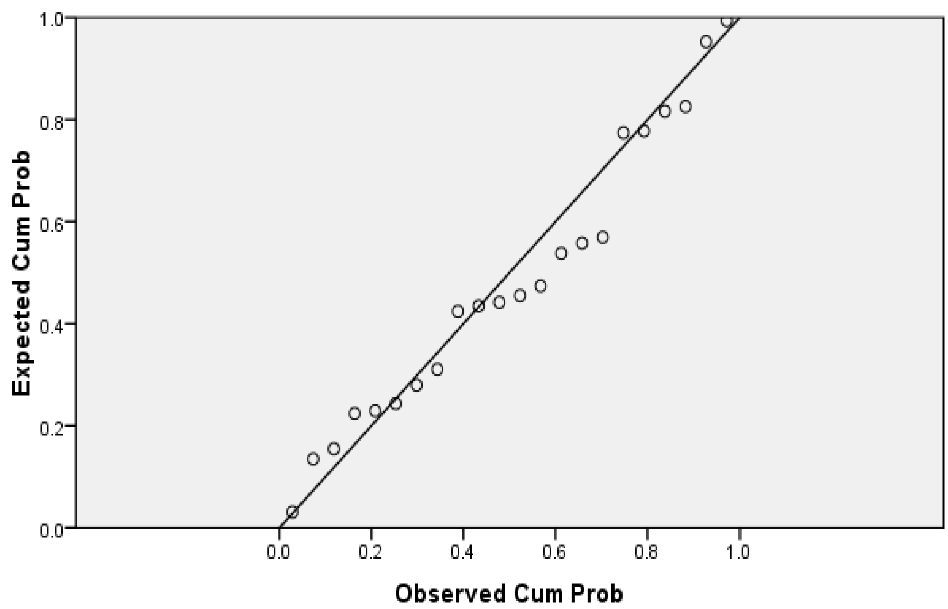



Figure 8.2: Normal P-P plot of standardised residuals-H1

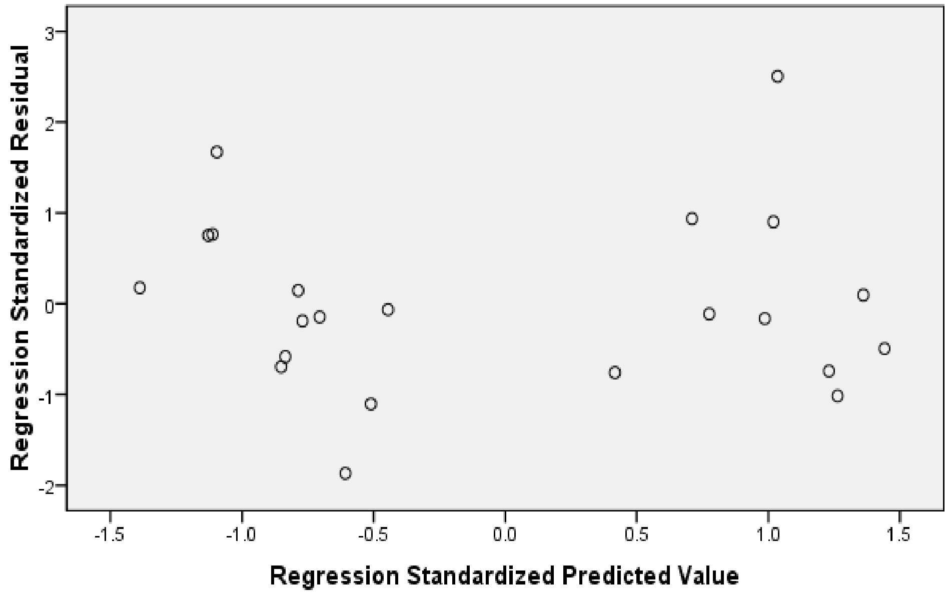



Figure 8.3: Scatter plot of standardised residuals-H1

Figure 8.1 shows a bell-shaped distribution and Figure 8.2 also shows points generally lying close to the straight diagonal line. These indicate that the assumption of normality has not been violated. Linearity of the relationship between variables was assessed by examining Figure 8.3. The random distribution of data points indicates that there is no evidence of a non-linear relationship and therefore this assumption has also not been violated. To test for the independence of the error terms, the Durbin-Watson statistic was obtained (as given in Table 8.16). Its value of 1.264 is between 1 and 3 indicating that this assumption has also not been violated.

Taken together, the results thus support the hypothesis that, *the degree to which a proximal factor(s) is common/prevalent within a CPF will be positively and significantly related to the degree of potential of the CPF to influence accident occurrence.*

### 8.5.2 The Moderating Effect of Degree of Potential of Proximal Factor(s) to Influence Accident Occurrence

Hypothesis H2 posits that the degree of potential of a proximal factor(s) to influence accident occurrence moderates the relationship between the prevalence of the proximal factor(s) within its CPF and the degree of potential of the CPF to influence accident occurrence such that the relationship becomes more positive as the potential of the proximal factor(s) to influence accident occurrence becomes more positive. To test for the existence of moderation the outcome variable (i.e. degree of potential of CPF to influence accident occurrence), the independent variable (i.e. degree of prevalence of proximal factor(s) within CPF), the moderator variable (i.e. the degree of potential of proximal factor(s) to influence accident occurrence) and the moderator effect (i.e. the product of the degree of prevalence of proximal factor(s) within CPF and the degree of potential of proximal factor(s) to influence accident occurrence) were applied in the regression analysis. The test of moderation is the significance of the moderator effect (i.e. R x r) so that the moderator hypothesis is supported if the moderator effect (i.e. R x r) is significant (Baron and Kenny, 1986; Hair *et al.*, 2010). As previously indicated, step-wise method of regression was applied and the output of the analysis is given in Table 8.17.

As shown by Table 8.17 only the moderator effect was selected for inclusion in the model. The value of $R^2$ for the model generated is .859, implying that the moderator effect accounts for 85% of the variation in potential of CPF to influence accident occurrence. The analysis of variance (ANOVA) which tests whether or not the model is a useful predictor of potential of CPF to influence accident occurrence, gives a highly significant result ($F = 121.759$, $p < .001$), indicating that this model significantly improves the prediction of potential of CPF to influence accident occurrence. Again the t-test for the ß-value of the moderator effect (t =

4.700, $p < 0.001$) is strong evidence that the moderator effect significantly predicts the degree of potential of CPF to influence accident occurrence. The ß-value being positive also indicates a positive relationship. As the focus of the hypothesis test is to test for the presence of moderation, the ß-value of the moderator effect being significant (ß = 0.241, $p < 0.001$) is evidence of moderation. To test the assumptions of the regression, an analysis of residuals was undertaken. Plots of the residuals are shown in Figures 8.4, 8.5 and 8.6.

Figure 8.4 shows a bell-shaped distribution and Figure 8.5 also shows points generally lying close to the straight diagonal line. These indicate that the assumption of normality has not been violated. Linearity of the relationship between variables was assessed by examining Figure 8.6. The random distribution of data points indicates that there is no evidence of a non-linear relationship and therefore this assumption has also not been violated. To test for the independence of the error terms, the Durbin-Watson statistic was obtained (as given in Table 8.17). Its value of 1.201 is between 1 and 3 indicating that this assumption has also not been violated. Taken together, the results thus support hypothesis H2.

Table 8.17: Regression analysis for the moderation effect of degree of potential of proximal factor(s) to influence accident occurrence

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R | .927 | $R^2$ | .859 | Adjusted $R^2$ | .852 | | |
| Std. Error | .19785 | $R^2$ Change | .859 | Durbin-Watson | 1.201 | | |
| Analysis of variance | df | Sum of Squares | Mean Square | F | Sig. | | |
| Regression | 1 | 4.766 | 4.766 | 121.759 | .000 | | |
| Residual | 20 | .783 | .039 | | | | |
| Total | 21 | 5.549 | | | | | |
| Variables in equation | B | Std. Error | Beta | t | Sig. | Tolerance | VIF |
| (Constant) | .671 | .143 | | 4.700 | .000 | | |
| Moderator Effect (i.e. R x r) | .241 | .022 | .927 | 11.034 | .000 | 1.000 | 1.000 |

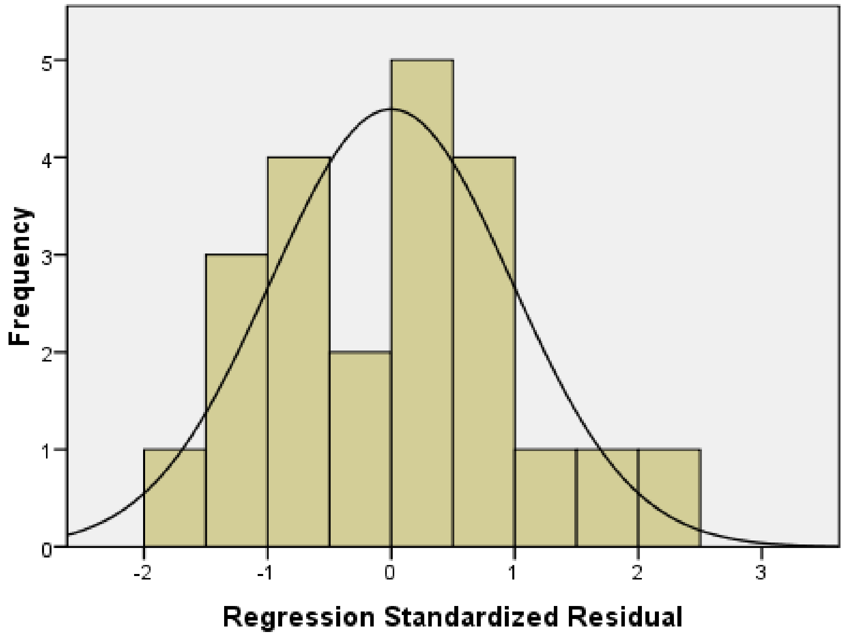



Figure 8.4: Histogram of standardised residuals-H2

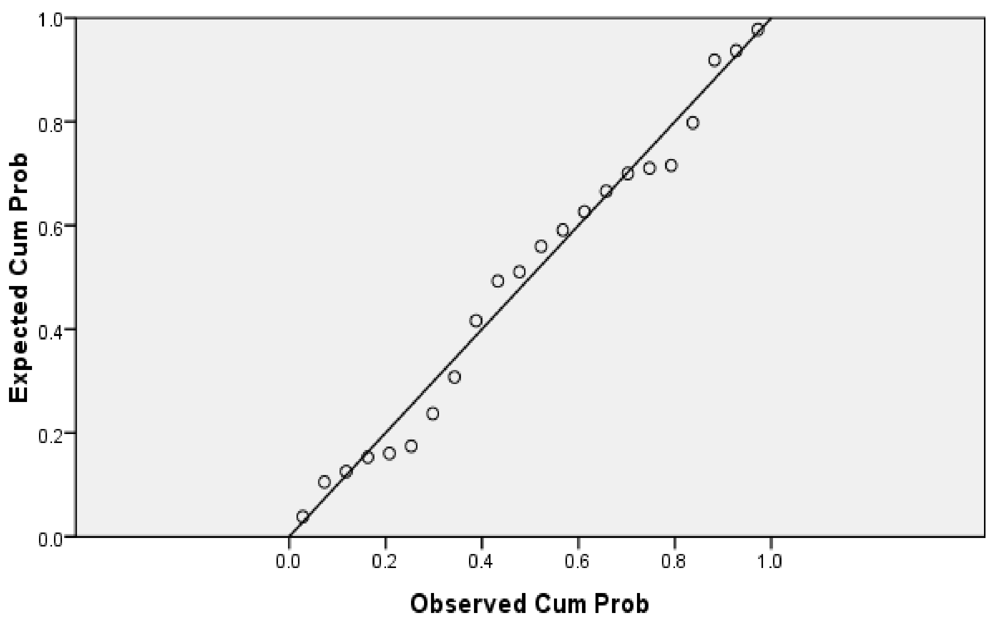



Figure 8.5: Normal P-P plot of standardised residuals-H2

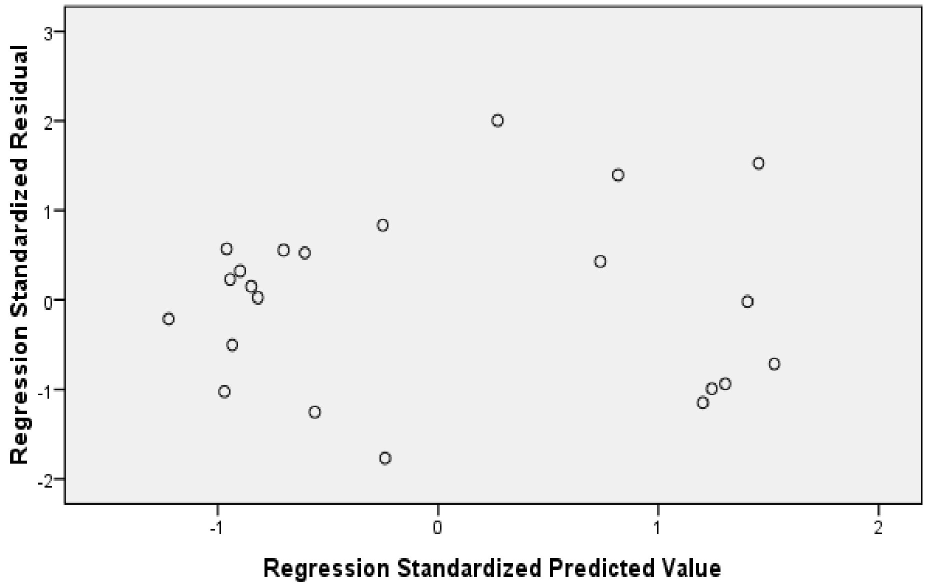



Figure 8.6: Scatter plot of standardised residuals-H2

### 8.5.3 Discussion

The results of the test of the two hypotheses indicate that both hypotheses are supported. This indicates that the degree of potential of a CPF to influence accident occurrence is indeed affected by:

- the extent to which its proximal factor(s) is prevalent/common within the CPF; and
- the degree of potential of its proximal factor(s) to influence accident occurrence.

The findings concur with the suggestion in literature that the varying degree of potential of CPFs to influence accident occurrence is due to the varying extent to which proximal factors are common/prevalent within CPFs. This was summarised and presented by Table 5.2. For instance it was suggested that demolition and refurbishment have greater potential to influence accident occurrence as a result of greater extent of uncertainty of hazards within demolition and refurbishment than within new work (cf. Egbu, 1999; Anumba *et al.*, 2006; Hughes and Ferrett, 2008).

The findings also provide empirical evidence in support of the argument that the degree of potential of a CPF to influence accident occurrence is not just influenced by the degree of prevalence of its proximal factor(s) within it, but is also influenced by the degree of potential of its proximal factor(s) to influence accident occurrence (Manu *et al.*, 2010). In likeness to the argument put forward by Duffus and Worth (2001) in support of the influence of exposure on risk, this argument was based on the logic that it is by reason of the proximal factor causing accidents (i.e. having the potential to cause accidents) that the CPF is able to contribute to accident occurrence through its inherent introduction of the proximal factor.

The findings imply that, greater prevalence of a proximal factor(s) within a CPF yields greater potential of the CPF to influence accident occurrence, albeit this effect is moderated by the potential of the proximal factor(s) to influence accident occurrence so that greater potential of proximal factor(s) to influence accident occurrence yields even greater potential of the CPF to influence accident occurrence. This means that, greater prevalence of a proximal factor(s) within a CPF (i.e. ***r***) coupled with greater potential of the proximal factor(s) to influence accident occurrence (i.e. ***R***) yields greater potential of CPF to influence accident occurrence (i.e. ***C***). A lesser '***r***' coupled with a greater '***R***', and conversely, a lesser '***R***' coupled with a greater '***r***', yields a lesser '***C***'. Also a lesser '***r***' coupled with a lesser '***R***', yields a lesser '***C***'. Mitigation of the degree of potential of a CPF to influence accident occurrence can thus be achieved by mitigating the prevalence of proximal factors within CPFs and/or by mitigating the potential of proximal factors to influence accident occurrence.

The findings provide some scope for explaining the surprising overall assessments obtained for the degree of potential of CPFs to influence accident occurrence. From the assessment, it was found that the procurement methods are generally perceived as having similar potential to influence accident occurrence (i.e. *moderate*) (indicated in Table 8.10). It was also found that the degree to which fragmentation of project team is common/prevalent within the procurement methods is similar (i.e. *moderate*) (indicated in Table 8.14). In view of the supported Hypothesis *H1* it is thus only consequential that the procurement methods generally have a similar potential to influence accident occurrence as the extent of fragmentation of project team within them is generally assessed as being similar. Therefore, a reasonable explanation for the procurement systems having similar potential to influence accident occurrence is that there is similar degree of fragmentation of project team within them.

Another surprising finding from the overall assessment of the degree of potential of CPFs to influence accident occurrence was that pre-assembly construction and traditional on-site construction are generally considered as having a similar degree of potential to influence accident occurrence (i.e. *moderate* potential). A plausible reason that was put forth was that manual handling may be becoming safer within the industry (i.e. safer manual handling techniques are being introduced and practised within the industry) and this was based on the assumption that the degree of potential of CPFs to influence accident occurrence is also affected by the degree of potential of their proximal factors to influence accident occurrence. The overall assessment of the potential of proximal factors to influence accident occurrence (given in Table 8.12) showed that manual handling and mechanical handling are both generally assessed as having a *moderate* potential to influence accident occurrence and thus giving some indication that manual handling could be becoming safer in the industry. Therefore, in view of the supported Hypothesis *H2*, one reasonable explanation for the surprising assessment is that it can be due to safer manual handling practices within the industry which are making traditional on-site construction safer. Given efforts to address manual handling such as The Manual Handling Operations Regulations 1992 (amended in 2002) and supporting revised industry guidance such as "*Getting to Grips with Manual Handling*" (INDG143(rev2) by the HSE (2011c) this is very much likely to be the case. Again, the overall assessment of the extent to which proximal factors are common within CPFs (given in Table 8.14) showed that the extent to which mechanical handling is common/prevalent within traditional construction and pre-assembly is generally considered as being similar (i.e. moderate). In view of the supported Hypothesis *H1*, another plausible explanation for the surprising finding is that it can also be partly due to similar extent of mechanical handling within both methods of construction, which perhaps (as alluded to) could also be due to increasing construction technologies requiring more mechanical means of handling for in-situ construction.

Overall, as the degree of potential of CPFs to influence accident occurrence is a determinant of the degree of H&S risk associated with CPFs, the results of the test of hypotheses provide evidence based justification for devising and implementing risk control measures targeted at mitigating the degree of potential of CPFs to influence accident occurrence and hence their associated H&S risk. Such measures could either be directed towards mitigating the degree of prevalence of proximal factors within CPFs and/or mitigating the degree of potential of proximal factors to influence accident occurrence (i.e. their potential to cause harm). Mitigating the potential of proximal factors to cause harm implies implementing measures which make proximal factors safer or measures which make it safe for workers to operate within conditions imposed by proximal factors. Such measures could take the form of using personal protective equipment. For instance in the case of working at height and work in confined space, PPE could be useful. In the case of some proximal factors such as situations of time-pressure or a fragmented workforce, increased supervision may be useful. It should however be noted that in terms of the hierarchy of risk control, measures such as PPE are a last resort and as such greater emphasis should be placed on the removal or substantial reduction of the prevalence of proximal factors.

## 8.6 RESULTS FROM THE GENERAL INFORMATION

Aside the response to close ended questions, the survey requested general comments (via open-ended questions) on the accident causal influence of CPFs and construction accident causation. To facilitate the validation of the entire research findings at the latter stage of the research, the survey also queried the participants' interest in receiving the research findings and also their interest in participating in a further phase of the research. The responses in relations to these are presented in the next two sections.

### 8.6.1 General Comments on the Accident Causal Influence of CPFs and Construction Accident Causation

A third of the participants provided brief general comments. In the main the comments emphasised the accident implications of CPFs and the need for that to be addressed early in project procurement. Some comments also highlighted other important aspects of H&S such as the role of leadership by clients and senior management of construction organisations and also improving the behaviour of frontline workers. These reflect the multi-dimensional nature of construction accident causation (cf. Suraji *et al.*, 2001; Haslam *et al.*, 2005).

In terms of the accident causal influence of CPFs, two CPFs were frequently mentioned by participants as being a major concern within the industry. These are tight project schedules and designs with features which impinge on buildability. Participants were of the view that quite often little consideration is given by clients and their design and project management teams as to the H&S impact of these features despite the requirements under the CDM 2007 for clients to allow adequate time for each stage of a project and for designers to take buildability and maintainability of designs into account. In connection to this, CDM Coordinators were portrayed as not being of much influence in advising clients and their design and project management teams on these matters. Some of the comments indicating these concerns are given below:

> *"In my experience the two greatest factors that influence accidents on site are time constraints-programme, and design buildability."* [H&S Manager]
>
> *"There is still not enough done under CDM to design out risk on site."* [H&S Manager]
>
> *"Design buildability. Designer to explain in detail how to build what they design. If not possible then design should be simplified."* [H&S Manager]
>
> *"Time pressure-particularly with contracts that incur penalty or client displeasure- is I believe one of the greatest influences on the implementation and management of safety on site."* [H&S Manager]
>
> *"The CDM Regs. stipulates that time is a resource. It is my experience that CDM-Coordinators do not challenge project timescales, and contractors due to scarcity of work are willing to take on the challenge and increased risk factors."* [H&S Manager]

In all, these comments reiterate the views expressed by participants in the qualitative inquiry that tight schedules and designs with poor buildability are commonplace within the industry and have accident implications.

An interesting view point that was also expressed is that projects with features of higher risk are more likely to be controlled better during construction and as such are more likely to be safer than projects with features of lesser risk, as there tends to be greater attention to H&S on projects with features of greater risk. This is demonstrated by the following comments.

> *"High risk activities and sites with restricted space tend to be well planned and managed."* [H&S Manager]

> *"Most accidents occur in everyday situations rather than 'high risk' situations which are usually well planned and monitored."* [H&S Manager]

This view reflects comments from the qualitative inquiry that although some CPFs may be more dangerous than others, the actual occurrence of accidents largely depends on the control measures that are put in place. The implication therefore is that CPFs, whether *high-risk, medium-risk, or low-risk,* should not be underestimated and that risk control measures that are commensurate with the degree of risk should be implemented and continually reviewed. This is reflected by a comment that:

> *"Any project feature can influence the occurrence of an accident. However it is the control of those project features that are essential. If suitable and sufficient risk assessments are carried out then the influence of those features can be kept to a minimum."* [H&S Manager]

Interestingly, some participants were of the view that partnering and collaborative working in the industry is ineffective. This view is corroborated by the quantitative analysis and it gives indication of scepticism as to the presence of 'true' partnering and collaborative working culture in the industry as there is some impression that clients are more concerned with their own interests, such as shorter project timescales, and some of these interests are inimical to H&S.

> *"Partnering and collaborative working has collapsed. This is having a significant effect on site H&S performance."* [H&S Manager]

> *"Many projects have short timescales. Clients just want the principal contractor on site and working. They do not care whether the project is buildable or not…The CDM Coordinators that we work with in general do not assist in the identification of hazards or controlling them."* [Health, Safety, Environmental and Quality Manager]

Overall, the additional comments given by the participants have raised concerns which buttress aspects of the findings of the quantitative assessment and the qualitative inquiry.

### 8.6.2 Participants' Interest in Research Findings and Further Participation in Study

The responses in respect of participants' interest in the research findings and in further participation in the study are indicated in Table 8.18 and Table 8.19.

Table 8.18: Interest in participation in a further phase of the research

| Category | Frequency | Percentage (%) |
|---|---|---|
| Interested participants | 70 | 38.04% |
| Non-interested participants | 104 | 56.52% |
| Unspecified | 10 | 5.43% |
| Total | 184 | 100% |

Table 8.19: Interest in research findings

| Category | Frequency | Percentage (%) |
|---|---|---|
| Interested participants | 105 | 57.07% |
| Non-interested participants | 70 | 38.04% |
| Unspecified | 9 | 4.89% |
| Total | 184 | 100.00% |

From Table 8.18, approximately 40% of participants are interested in participating in a further phase of the research. Given the difficulty in obtaining participation in research, and particularly H&S research in UK (cf. Gibb et al., 2002), this value is reasonable. From Table 8.19, approximately 60% of the participants are interested in receiving the research findings. This suggests a good deal of interest in the subject under investigation and its relevance to industry.

## 8.7 SUMMARY

This chapter sought to assess the degree of potential of CPFs to influence accident occurrence including the verification of the related hypothesised relationships.

Based on the judgement of experienced construction professionals, it was found that, CPFs generally have a *moderate* potential to influence accident occurrence or a *high* potential to influence accident occurrence (in others word a fair potential to cause harm or a severe potential to cause harm in terms of the H&S of workers). Amongst the CPFs which have a moderate potential are: simple design, single-layer subcontracting, adequate project duration, and low-level construction. Amongst the CPFs which have a *high* potential are: demolition, tight project duration, multi-layer subcontracting, and complex design. Intriguingly, it was found that all the procurement methods (i.e. management contracting, partnering procurement, design and build procurement, and traditional procurement) have a *moderate* potential and also both traditional construction and pre-assembly construction are considered as having a *moderate* potential.

From the test of hypotheses, it was confirmed that the degree of potential of a CPF to influence accident occurrence is influenced by two factors: the extent to which its proximal accident factor(s) is common/prevalent within it; and the degree of potential of the proximal factor(s) to influence accident occurrence. These findings are significant as they provide evidence based justification for devising and implementing measures aimed at mitigating the potential of CPFs to influence accident occurrence. The findings also offer some scope for explaining the surprising assessments concerning the procurement methods and methods of construction. In that regard it can be inferred that the *moderate* potential to influence accident occurrence accorded to the procurement methods is due to a similar extent of fragmentation of project team within the procurement methods which was found from the assessment of the extent to which proximal factors are common within CPFs. It can also be inferred that the *moderate* potential to influence accident occurrence accorded to both pre-assembly construction and traditional construction is partly due to safer manual handling practices being applied in industry as manual handling and mechanical handling are both considered as having a similar potential to influence accident occurrence (i.e. *moderate*).

Overall, the assessment carried out accords each CPF the degree of its potential to influence accident occurrence which in effect allows for comparison amongst all the CPFs. The variance in the degree of potential of CPFs to influence accident occurrence evident from the analyses (i.e. moderate or high) once again emphasises the need for pre-construction project participants to re-think the CPFs they propose for delivering projects. As indicated by the assessment and the general comments, CPFs such as intricate project designs and unrealistic project schedules which have *high* potential to influence accident occurrence are a major concern in the industry. Other CPFs which have *moderate* potential to influence accident occurrence can however not be underestimated.

By presenting the results of the assessment of the degree of potential of CPFs to influence accident occurrence, this Chapter has partly addressed the fourth research objective. Complete achievement of the fourth objective requires the evaluation of the degree of H&S risk associated with CPFs. This is considered in the next chapter together with the fifth research objective which is to consolidate the research findings by the development of a simple H&S risk management toolkit.

# CHAPTER 9: QUANTITATIVE FINDINGS 2 - DEGREE OF H&S RISK ASSOCIATED WITH CONSTRUCTION PROJECT FEATURES - & DEVELOPMENT OF H&S RISK MANAGEMENT TOOLKIT

## 9.0 INTRODUCTION

In the previous chapter, the degree of potential of CPFs to influence accident occurrence (i.e. potential to cause accident/harm), which is the first facet of the measurement framework was assessed. The second facet of the measurement framework which is the H&S risk associated with CPFs (i.e. the likelihood of occurrence of accident/harm) now needs to be assessed by applying the adapted H&S risk expression. Drawing on the assessment of the degree of potential of CPFs to influence accident occurrence, this chapter thus presents the assessment of the degree of H&S risk associated with CPFs. Using the adapted H&S risk expression, the aggregated measures (i.e. mean ratings) of the degree of potential of CPFs to influence accident occurrence are combined with workforce exposure in a risk combination matrix.

Following the assessment of H&S risk, the entire research findings from both the qualitative and quantitative inquiries are then consolidated by developing a simple H&S risk management toolkit to provide a repository of the research findings which could assist in pre-construction H&S planning. This chapter therefore completes the achievement of the fourth research objective by the assessment of the degree of H&S risk associated with CPFs. The chapter also addresses the fifth research objective which is to consolidate the findings of the research by a simple H&S risk management toolkit which focuses on the accident causal influence of CPFs.

## 9.1 ASSESSMENT OF H&S RISK ASSOCIATED WITH CPFs

From Chapter 4, it was found that a semi-quantitative risk evaluation using a risk combination matrix is ideal for evaluating the H&S risk associated with CPFs. Semi-quantitative risk evaluation provides a 'midway' risk evaluation approach which lies between the textual evaluation of qualitative risk evaluation and the numerical evaluation of quantitative risk evaluation. It offers a more consistent and rigorous approach to evaluating and comparing risks than does qualitative risk assessment, and avoids some of the greater ambiguities that a qualitative risk assessment may produce (WHO and FAO, 2009). Again semi-quantitative risk evaluation does not require the same mathematical skills as quantitative risk evaluation, nor does it require the same amount of data, which means it can be applied where precise data are missing or unavailable. It is for these reasons that a semi-quantitative risk evaluation was chosen as being the most appropriate for evaluating the H&S risk associated with CPFs.

As previously noted, this approach however has a weakness which is that the resulting risk scores are placed into usually quite broad sets of categories (e.g. risk score 0-3 = Low risk, risk score 4-7 = Medium risk, and risk score 8-10 = High risk). This weakness can however be overcome if the categories are carefully constructed (WHO and FAO, 2009). In constructing the various categories of risk levels in the assessment of the H&S risk associated with CPFs, the approach of the British Standard Institution (2008) served as a useful guide. The British Standard Institution (2008) proposes a five band risk categorization and acceptability as shown in Table 9.1 below. For the assessment of the H&S risk associated with CPFs this five band categorisation was adopted.

Table 9.1: Risk categorisation and acceptability guidance

| **Category of risk** | **Evaluation of Acceptability** |
|---|---|
| Very Low | Risk is considered acceptable. No further action is necessary other than to ensure that the controls are maintained. |
| Low | No additional controls are required unless they can be implemented at very low cost (in terms of time, money and effort). Actions to further reduce these risks are assigned low priority. |
| Medium | Consideration should be given as to whether the risks can be lowered, but the costs of additional risk reduction measures should be taken into account. |
| High | Substantial efforts should be made to reduce the risk. Risk reduction measures should be implemented urgently. |
| Very High | Risk is unacceptable. Substantial improvements in risk controls are necessary, so that the risk is reduced to an acceptable level. |

Source: British Standard Institution (2008)

As usual with semi-quantitative risk evaluation, risk categories are assigned to numeric risk scores and to achieve this, the adapted risk expression was applied. It was proposed in Chapter 4 that the *H&S risk associated with a CPF (i.e. Rk) = Degree of potential of the CPF to influence accident occurrence (i.e. C) x Exposure* (Adapted from Chicken and Posner, 1998; Duffus and Worth, 2001; Canadian Centre for Occupational Health and Safety, 2008). Degree of potential of CPFs to influence accident occurrence has been assessed using a 5-point scale (0 = None, 1 = Low, 2 = Moderate, 3 = High, and 4 = Very High). It has been argued that in the context of CPFs due to their remoteness in the process of accident causation, workforce exposure to their potential to influence accident occurrence (in other words their potential to cause harm in terms of H&S) can realistically be assessed at a generic meta-project level such as in the form of the duration within which a CPF applies on a project or by broadly assessing exposure in terms of whether or not a CPF applies to a project (cf. Manu *et al.*, 2012a). However, given the difficulty in assessing exposure in terms of duration for some CPFs (e.g. level of construction and subcontracting) as previously discussed in Section 5.3.2, it was resolved that assessing exposure in terms of whether or not a CPF applies to a project is a more viable option (see Section 5.3.2). This means that, if a CPF applies to a project the workforce will be exposed to its potential to influence accident occurrence and where a particular CPF does not apply to a project, the workforce will not be exposed to its potential to influence accident occurrence. In line with semi-quantitative risk evaluation where qualitative information are assigned numeric scales, assessing exposure in this manner can be expressed as a binary situation where 'zero' is assigned to a no exposure condition and 'one' is assigned to a condition where the workforce is exposed. It is logical assigning 'zero' to a no exposure situation because without exposure there can be no risk (Duffus and Worth, 2001; HSE, 2001) and as such any degree of potential to influence accident occurrence combined (i.e. multiplied) with a no exposure condition will yield no risk.

Having determined a semi-quantitative scale for expressing exposure, (i.e. 0 = workforce not exposed - where a CPF does not apply to a project; and 1 = workforce exposed - where a CPF applies to a project), the adapted risk expression was then applied using a risk combination matrix as given in Table 9.2 below.

Table 9.2: Risk combination matrix

| | | **Exposure** | |
|---|---|---|---|
| | | 0 | 1 |
| **Potential to influence accident occurrence** | 0 | ***0*** | ***0*** |
| | 1 | ***0*** | ***1*** |
| | 2 | ***0*** | ***2*** |
| | 3 | ***0*** | ***3*** |
| | 4 | ***0*** | ***4*** |

From the above risk combination matrix, the H&S risk associated with a CPF can range from a score of 0 (being the least) to 4 (being the highest). These numeric levels of risk need to be assigned qualitative risk categories to enable interpretation of the risk matrix and it is here that the risk categorisation proposed by the British Standard Institution (2008) (i.e. Table 9.1) was very useful. As no exposure results in no risk and similarly the absence of potential to cause harm also results in no risk (Duffus and Worth, 2001; HSE, 2001), the '0' risk value was assigned a 'No risk' category. Risk score '4' being the highest, was thus assigned a 'Very high risk' category, and risk score '2' being the mid score was assigned a 'Medium risk' category. Risk score '1' being the next risk score below risk score '2' was assigned a 'Low risk' category and finally risk score '3' being the next risk value above risk score '2' was assigned a 'High risk' category. Assigning such risk categories to the numeric scores, leads to an interpretable risk combination matrix given by Table 9.3 which enables interpretation of the numeric risk scores. Following this careful construction of the risk categories, the H&S risk associated with CPFs was assessed using the mean measures of degree of potential of CPFs to influence accident occurrence obtained from Chapter 7. The risk assessment is given by the risk combination matrix in Table 9.4.

Table 9.3: Risk combination matrix with assigned risk categories

| | | **Exposure** | |
|---|---|---|---|
| | | 0 | 1 |
| **Potential to influence accident occurrence** | 0 | ***0 (No risk)*** | ***0 (No risk)*** |
| | 1 | ***0 (No risk)*** | ***1 (Low risk)*** |
| | 2 | ***0 (No risk)*** | ***2 (Medium risk)*** |
| | 3 | ***0 (No risk)*** | ***3 (High risk)*** |
| | 4 | ***0 (No risk)*** | ***4 (Very high risk)*** |

From the assessment, where a CPF applies to a project, demolition has the highest degree of risk (i.e. risk score 3.17) and pre-assembly construction has the lowest degree of risk (i.e. risk score 1.51). To assist in better interpretation of the numeric risk scores, they are approximated to the nearest risk score and this yields the overall assessment given by Table 9.5. The overall assessment is discussed in the following section.

Table 9.4: Risk combination matrix for assessment of the H&S risk associated with CPFs

| | | Exposure | |
|---|---|---|---|
| **Construction Project Features** | **Degree of Potential to influence accident occurrence (i.e. C)** | **0** | **1** |
| Demolition | 3.17 | 0 | 3.17 |
| Underground construction | 2.84 | 0 | 2.84 |
| Tight project duration | 2.84 | 0 | 2.84 |
| High-level construction | 2.76 | 0 | 2.76 |
| Multi-layer subcontracting | 2.7 | 0 | 2.7 |
| Complex design | 2.61 | 0 | 2.61 |
| Restricted site | 2.61 | 0 | 2.61 |
| Restricted site locality | 2.57 | 0 | 2.57 |
| Refurbishment | 2.52 | 0 | 2.52 |
| Traditional on-site construction | 2.22 | 0 | 2.22 |
| New work | 1.99 | 0 | 1.99 |
| Management contracting | 1.95 | 0 | 1.95 |
| Design and build procurement | 1.83 | 0 | 1.83 |
| Traditional method of procurement | 1.81 | 0 | 1.81 |
| Unrestricted site locality | 1.8 | 0 | 1.8 |
| Unrestricted site | 1.79 | 0 | 1.79 |
| Partnering procurement | 1.77 | 0 | 1.77 |
| Low-level construction | 1.71 | 0 | 1.71 |
| Adequate project duration | 1.66 | 0 | 1.66 |
| Single-layer subcontracting | 1.63 | 0 | 1.63 |
| Simple design | 1.55 | 0 | 1.55 |
| Pre-assembly construction | 1.51 | 0 | 1.51 |

Table 9.5: Overall degree of H&S risk associated with CPFs where a CPF applies to a project

| **Construction Project Features** | **Risk Scores** | **H&S Risk associated with CPF where CPF applies to a Project** | |
|---|---|---|---|
| | | **High Risk (3)** | **Medium Risk (2)** |
| Demolition | 3.17 | ✓ | |
| Underground construction | 2.84 | ✓ | |
| Tight project duration | 2.84 | ✓ | |
| High-level construction | 2.76 | ✓ | |
| Multi-layer subcontracting | 2.7 | ✓ | |
| Complex design | 2.61 | ✓ | |
| Restricted site | 2.61 | ✓ | |
| Restricted site locality | 2.57 | ✓ | |
| Refurbishment | 2.52 | ✓ | |
| Traditional on-site construction | 2.22 | | ✓ |
| New work | 1.99 | | ✓ |
| Management contracting | 1.95 | | ✓ |
| Design and build procurement | 1.83 | | ✓ |
| Traditional method of procurement | 1.81 | | ✓ |
| Partnering procurement | 1.8 | | ✓ |
| Pre-assembly construction | 1.79 | | ✓ |
| Unrestricted site locality | 1.77 | | ✓ |
| Unrestricted site | 1.71 | | ✓ |
| Low-level construction | 1.66 | | ✓ |
| Adequate project duration | 1.63 | | ✓ |
| Single-layer subcontracting | 1.55 | | ✓ |

Notes: Where a CPF does not apply to a project there is no risk due to that CPF on the project

## 9.1.1 Discussion

From Table 9.5, the degree of H&S risk associated with a CPF where it applies on a project can be generally considered as either being *high risk* or *medium risk*. Amongst the 22 CPFs, 9 are *high risk* features implying they are associated with a high likelihood of accident occurrence. The remaining 13 CPFs are *medium risk* features implying they are associated with *medium* likelihood of accident occurrence. Given the mode of exposure assessment and also given that risk derives from degree of potential to cause harm (which in this study is the degree of potential to influence accident occurrence) it is not surprising that the overall risk assessment given by Table 9.5 mirrors the overall assessment of the degree of potential of CPFs to influence accident occurrence. The CPFs which have a high degree of potential to influence accident occurrence are associated with *high risk* and the CPFs which have a moderate potential to influence accident occurrence are associated with *medium risk*. It is therefore not surprising that the overall risk assessment is consistent with the very few comparative risk evaluations in literature such as new work being considered as having less risk than refurbishment (Anumba *et al.*, 2006). Contrary to pre-assembly construction being considered as having less degree of H&S risk than traditional method of construction (cf. McKay et al., 2002) the assessment given by Table 9.5 indicates that pre-assembly and traditional construction are both medium-risk CPFs. Again, as the risk assessment derives from the assessment of the degree of potential of CPFs to influence accident occurrence, this is not surprising. In terms of acceptability of risk, referring to the guidance by the British Standard Institution (2008), none of the CPFs is associated with acceptable risk indicating that whichever CPFs apply to a project, measures need to be undertaken to mitigate their associated risk, albeit the extent of the measures depends on the degree of risk. Whereas for medium risk CPFs consideration should be given as to whether risk can be lowered further, for high risk CPFs substantial measures are required to be implemented.

As expressed by interviewees at the qualitative phase, although these CPFs influence accident occurrence, the actual occurrence of accident on site depends on how the risk associated with them is effectively managed from the early stage of projects and this underscores the significance of effective H&S planning from the early stage of project procurement (Szymberski, 1997). Despite the established significance of pre-construction H&S planning to H&S, from the interviews at the qualitative phase and the general comments from the questionnaire survey, a common view is that unrealistic project schedules and intricate designs are commonplace. Some of the interviewees' comments highlighting this are as given below.

> *"My view at the moment is that clients do not fully appreciate that the programmes that they set are too tight. The problem is that they set it and people have to say that they'll work to it otherwise you're not going to win the job. And once you've said it you've got to stick to it otherwise you're going to get your LADs when you get to the end and you don't finish on time. In my view unrealistic programmes are a definite factor that increases risk. I don't think clients have fully understood that and I don't think clients have fully understood their responsibilities under the CDM regulations"* [H&S Manager]

> *"Architects and designers in some cases would say: that's the way the design is and so that's the way you'll build it. However, we can see problems with it…We try and point out these problems but some architects will say to you: that's my design, that's how I want it, and so that's how you build it- and that is a very difficult situation."* [H&S Manager]

In the light of the overall risk assessment, such *high risk* CPFs (e.g. unrealistic project schedules and intricate designs) should certainly not be taken lightly. The CDM 2007 places legal obligation on clients to allow sufficient time for all the stages of a project and it also imposes legal obligation on designers to make designs safer to construct. Adhering to such requirements should not be taken as being trivial or as a mere tick in the box exercise as there is a great likelihood of accidents occurring on projects where these features and similar *high risk* features apply. As CPFs emanate from the pre-construction stage of project procurement through decisions by the client, design team and project management team, these project participants have an enormous opportunity to mitigate the H&S risk associated with CPFs. In making decisions which determine CPFs, pre-construction decision makers could select *medium risk* CPFs over *high risk* CPFs as there is less likelihood of accident occurrence associated with *medium risk* CPFs. As the selection of a *high risk* CPF may be inevitable in some situations due to possible project constraints such as client requirements (Suraji et al., 2001), pre-construction project participants including the construction team would have to implement risk mitigation measures. In doing so, greater priority ought to be given to *high risk* CPFs and as such substantial efforts (i.e. resources) will have to be allocated towards mitigating the risk associated with *high risk* CPFs. With medium risk CPFs, as there is still some likelihood of accident occurrence where such CPFs apply, they cannot be totally disregarded. As recommended by the British Standard Institution (2008) further consideration ought to be given as to whether the risk can be reduced further while taking into account the cost of any measures.

In all, the overall risk assessment accords each CPF its degree of H&S risk which allows for comparison amongst all the CPFs. The overall risk assessment is an important insight into the accident causal influence of CPFs which should inform pre-construction decision-making regarding CPFs as well as the prioritisation of risk control measures. Touching on pre-construction H&S planning, it may be worth summarising the entire research findings by a simple H&S risk management toolkit to serve as a single repository of the research findings with the potential of assisting construction project participants in managing the accident causal influence of CPFs through pre-construction H&S planning. This is presented by the following sections.

## 9.2 TOWARDS THE DEVELOPMENT OF A SIMPLE H&S RISK MANAGEMENT TOOLKIT

This research set out to interrogate the accident causal influence of CPFs in order to answer three key questions:

- How do CPFs influence accident occurrence?
- What is the degree of potential of CPFs to influence accident occurrence? and;
- What is the degree of H&S risk associated with CPFs?

By the adoption of a mixed method approach these questions have been answered through the findings of the qualitative and quantitative inquiries thus bridging the knowledge gaps regarding the accident causal influence of CPFs. Given the need to effectively capture, store, disseminate and share knowledge as part of knowledge management (Bhatt, 2001; Mason and Pauleen, 2003; Hari *et al.*, 2005) which is important to the advancement of knowledge and performance in construction (Egbu, 2004; Anumba *et al.*, 2005; Egbu *et al.*, 2005), it stands to reason that the entire research findings are summarised in the form of a simple H&S risk management toolkit which serves as a single repository of the entire research findings. The risk information given by the toolkit could possibly assist pre-construction project participants in managing the accident causal influence of CPFs during pre-construction H&S planning. The following section presents a summary and consolidation of the research findings.

### 9.2.1 Summarising the Research Findings

In summarising the research findings, emphasis was laid on those aspects which succinctly address the research questions. It was also important for those aspects to be brought together in a coherent manner. To guide this process, the framework given by Figure 9.1 was applied. This framework shows the facets of the accident causal influence of CPFs investigated by the study which needed to be incorporated in the toolkit.

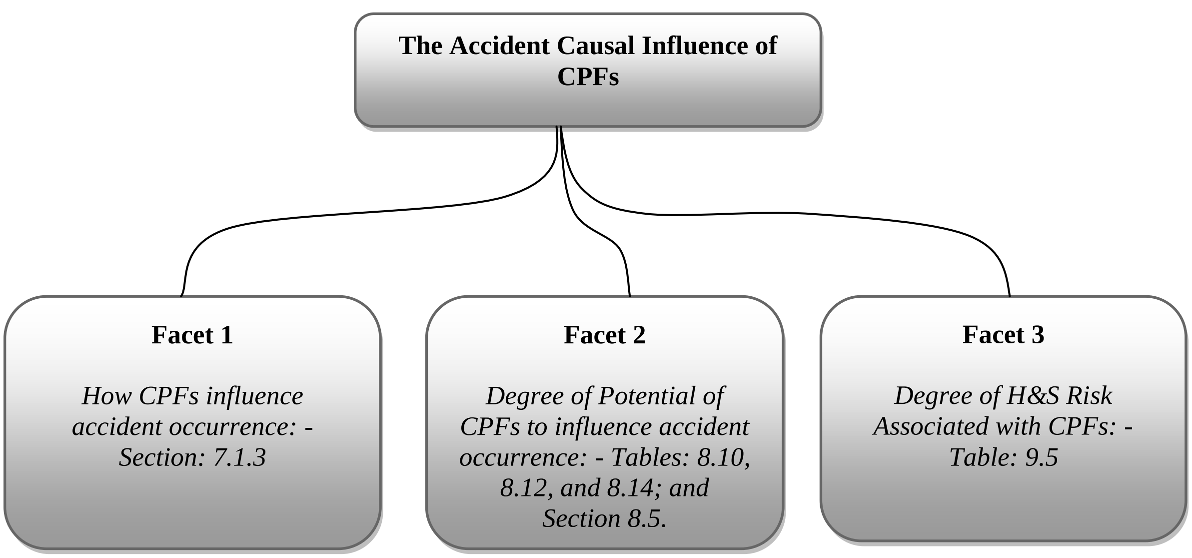



Figure 9.1: Facets of the accident causal influence of CPFs

In terms of how CPFs influence accident occurrence, it was found that:

- CPFs, being to a large extent the result of pre-construction decisions, are inherently associated with certain H&S issues (which can be termed *proximal accident factors* shown in Table 7.3) which they introduce into the construction phase and give rise to accidents.
- There are also causal interactions between CPFs and the proximal factors which can reduce or increase the presence of proximal factors.

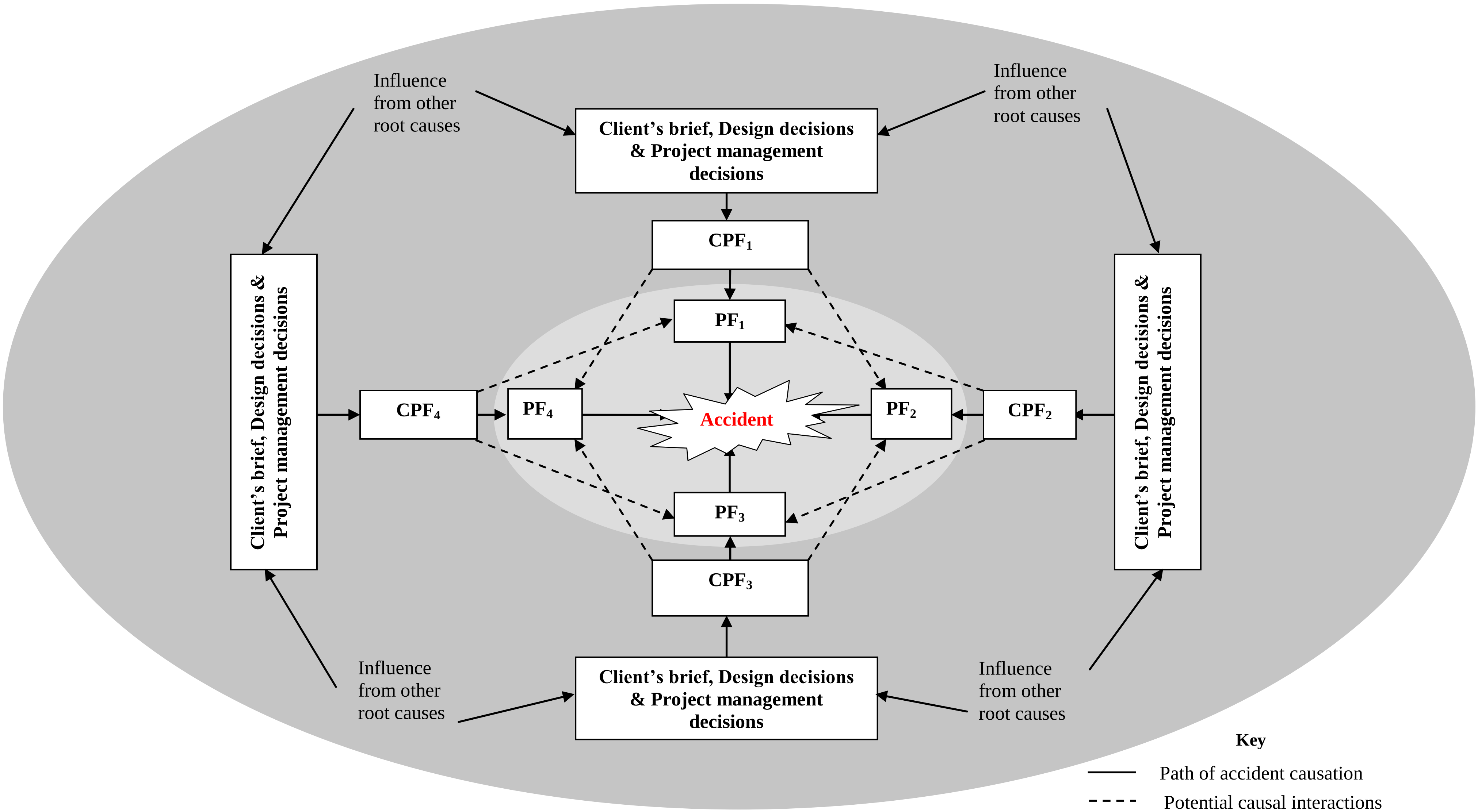
These findings provide verification of the conceptual model presented in Chapter 5 and can succinctly be presented as shown in Figure 9.2.

In terms of the degree of potential of CPFs to influence accident occurrence, it was found that CPFs generally have a *moderate* or *high* potential as given by Table 8.10. It was also found that the degree of potential of CPFs to influence accident occurrence is influenced by:

- the extent to which a proximal factor is common/prevalent within a CPF; and
- the degree of potential of the proximal factor to influence accident occurrence.

Based on these findings, Table 9.6 can be produced.

Concerning the degree of H&S risk associated with CPFs, it was found that CPFs are generally either *high risk* features or *medium risk* features. This means they are associated with a high likelihood of accident occurrence requiring the need for substantial risk control measures or they are associated with a medium likelihood of accident occurrence with some risk control measures being required. In presenting the entire research findings in a coherent manner, the findings of the degree of H&S risk associated with CPFs were amalgamated with Table 9.6 to produce Table 9.7, which for the sake of brevity indicates selected CPFs.




**Key**

Path of accident causation

Potential causal interactions

Construction stage

Pre-construction stage

CPF: Construction project feature

PF: Proximal factor

Figure 9.2: How CPFs influence accident occurrence

Table 9.6: Summary of the degree of potential of CPFs to influence accident occurrence incorporating the determining factors

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of potential of proximal factor to influence accident occurrence | Degree to which proximal factor is common/prevalent within CPF | Degree of potential of CPF to influence accident occurrence |
|---|---|---|---|---|
| Demolition | Uncertainty of hazards | High | High | High |
| Refurbishment | Uncertainty of hazards | High | High | High |
| New work | Uncertainty of hazards | High | Moderate | Moderate |
| High-level construction | Working at height | High | High | High |
| Low-level construction | Working at height | High | Moderate | Moderate |
| Underground construction | Working in confined space | High | High | High |
| Complex design | Difficulty in constructing i.e. buildability | High | High | High |
| Simple design | Difficulty in constructing i.e. buildability | High | Low | Moderate |
| Restricted site locality e.g. city centre | Difficulty in traffic control around site vicinity | High | High | High |
| Unrestricted site locality e.g. outer city | Difficulty in traffic control around site vicinity | High | Moderate | Moderate |
| Traditional on-site construction | Manual handling | Moderate | High | Moderate |
| | Mechanical handling | Moderate | Moderate | |
| | Housekeeping problems | High | High | |
| Pre-assembly construction | Manual handling | Moderate | Moderate | Moderate |
| | Mechanical handling | Moderate | High | |
| | Housekeeping problems | High | Moderate | |
| Tight project duration | Time-pressure | High | High | High |
| Adequate project duration | Time-pressure | High | Moderate | Moderate |
| Complex design | Difficulty in constructing | High | High | High |
| Simple design | Difficulty in constructing | High | Moderate | Moderate |

| **Construction Project Features (CPFs)** | **Proximal Factor Associated with CPF** | **Degree of potential of proximal factor to influence accident occurrence** | **Degree to which proximal factor is common/prevalent within CPF** | **Degree of potential of CPF to influence accident occurrence** |
|---|---|---|---|---|
| Design and build procurement | Fragmentation of project team | Moderate | Moderate | Moderate |
| Traditional procurement | Fragmentation of project team | Moderate | Moderate | Moderate |
| Management contracting | Fragmentation of project team | Moderate | Moderate | Moderate |
| Partnering procurement | Fragmentation of project team | Moderate | Moderate | Moderate |
| Multi-layer subcontracting | Fragmentation of workforce | Moderate | High | High |
| Single-layer subcontracting | Fragmentation of workforce | Moderate | Moderate | Moderate |
| Restricted site (i.e. where footprint of facility covers most of site area) | Site congestion | High | High | High |
| Unrestricted site (i.e. where footprint of facility covers a small portion of the site area) | Site congestion | High | Moderate | Moderate |

Drawing on the hierarchy of risk control and the factors which influence the degree of potential of CPFs to influence accident occurrence (and consequently their associated degree of H&S risk), suggestions regarding risk control measures for mitigating the accident causal influence of CPFs were incorporated in Table 9.7. These suggestions are: (1) avoidance of high risk CPFs (which may however not be possible especially where the project feature is inevitable due to client's requirements); (2) implementing measures to remove or reduce the prevalence of proximal factors; and (3) implementing measures to reduce the potential of proximal factors to influence accident occurrence. Table 9.7 illustrates an overall risk profile of the selected CPFs. The risk profile of the entire 22 CPFs is given in Appendix F. The risk profile is a succinct depiction of the research findings addressing the second and third research questions.

Table 9.7: H&S risk profile of selected CPFs

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of potential of proximal factor to influence accident occurrence | Degree to which proximal factor is common /prevalent within CPF | Degree of Potential of CPF to influence accident occurrence | Degree of risk associated with CPF (i.e. likelihood of accident occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Tight project duration | Time-pressure | High | High | High | ***High Risk*** | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid tight project duration through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce time-pressure. (3) Implement measures to reduce the potential of time-pressure to cause accidents. |
| Complex design | Difficulty in constructing | High | High | High | ***High Risk*** | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid complex design (i.e. design with intricate aesthetic qualities). Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce difficulty in constructing (i.e. buildability). (3) Implement measures to reduce the potential of difficulty in constructing (i.e. buildability) to cause accidents. |
| Design and build procurement | Fragmentation of project team | Moderate | Moderate | Moderate | ***Medium Risk*** | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce fragmentation of project team. (2) Implement measures to reduce the potential of fragmentation of project team to cause accidents. |
| Multi-layer subcontracting | Fragmentation of workforce | Moderate | High | High | ***High Risk*** | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid multi-layer subcontracting through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce fragmentation of workforce. (3) Implement measures to reduce the potential of fragmentation of workforce to cause accidents. |

*Adapted from the British Standard Institution (2008)

In view of having the research findings (as summarised by the model i.e. Figure 9.2, and the risk profile i.e. Appendix F) in a single repository, it is reasonable to use a computer application as computer applications are widely known to allow information to be stored, retrieved and shared with ease. The use of computer applications such as Microsoft Office in the construction industry is a widely known fact. Microsoft Office Project is for instance used in scheduling construction works (cf. Winter, 2011) and Microsoft Excel has also often been used in developing construction specific tools such as tools for structural analysis (cf. Goodchild and Webster, 2000) and estimating (cf. Peterson, 2011). Given the common use of Microsoft Office applications within the industry it was considered that using a Microsoft Office application to create a single repository for the accident model and risk profile would suffice. Microsoft Excel v 2010 was thus used. The following section presents how Microsoft Excel was used in this regard.

### 9.2.2 Using Microsoft Excel as a Repository for the Research Findings

Microsoft Excel, amongst its several functions for executing tasks, has a function called the “IF function” (Bluttman and Aitken, 2010). The IF function returns a value if a condition is true and another value if that condition is false (Bluttman and Aitken, 2010). This function can be very useful where among several possible scenarios a user wishes to display only the specific information relevant to a particular scenario. As different CPFs may apply to any single project, this function in Microsoft Excel can be used to create a series of instructions which retrieve and display only the risk profile related to a selection of CPFs which apply to a project. This function in Excel was used extensively.

To create the simple Microsoft Excel-based toolkit, the following steps were undertaken:

1. A worksheet was created for each of the following: an introduction page; a page depicting how CPFs influence accident occurrence; a page which allows for the selection of the CPFs which apply to a project; and a page which displays the H&S risk profile for every selected CPF which apply to a project and hence an overall H&S risk profile for a project in relation to its features.
2. On the introduction page, a brief introduction describing the purpose of the toolkit, its components and how it can be used was provided. On this page, a brief text indicating that the toolkit is the result of a PhD research was also provided. Information about the author, and the research supervisory team were also included on this page.
3. On the page indicating how CPFs influence accident occurrence, the accident model given by Figure 9.2 was presented together with a brief explanation.
4. On the page which allows for the selection of the CPFs, all the CPFs were indicated and grouped under organisational, physical and operational features. To enable the selection of only the CPFs which apply to a project a check box was assigned to each of the CPFs so that if a check box is ticked it would mean that its corresponding CPF applies to a project. A brief instruction was given on this page instructing users to tick the CPFs which apply to a project.
5. On the risk profile page, most of the IF function instructions which run the toolkit were inserted. The IF functions were linked to the page where CPFs are selected so that selecting a particular CPF automatically triggers a series of inserted IF functions on the risk profile page which eventually displays the risk profile for that CPF. Based on a selection of CPFs an approximate assessment of the degree of H&S risk associated with a project was also included in the risk profile in the form of a "mean" project risk. The measurement scales and a hierarchical list of the suggested risk control measures were also provided as additional information on this page.

6. Finally the various pages were linked together by the use of hyperlinks to enable ease of navigation from page to page.

The above steps were undertaken iteratively. Screenshots of the four worksheets of the toolkit are given by Figures 9.3 to 9.4 below. The eventual toolkit is named *CRiMT* which is an acronym for *CPFs Risk Management Toolkit*.

*CRiMT*, as a simple H&S risk management toolkit, provides in a unified succinct format the entire findings of this research addressing the key research questions posed to interrogate the accident causal influence of CPFs. It provides two key sets of information: how CPFs influence accident occurrence; and the H&S risk profile of a construction project in relation to its features.


Figure 9.3: Introduction worksheet

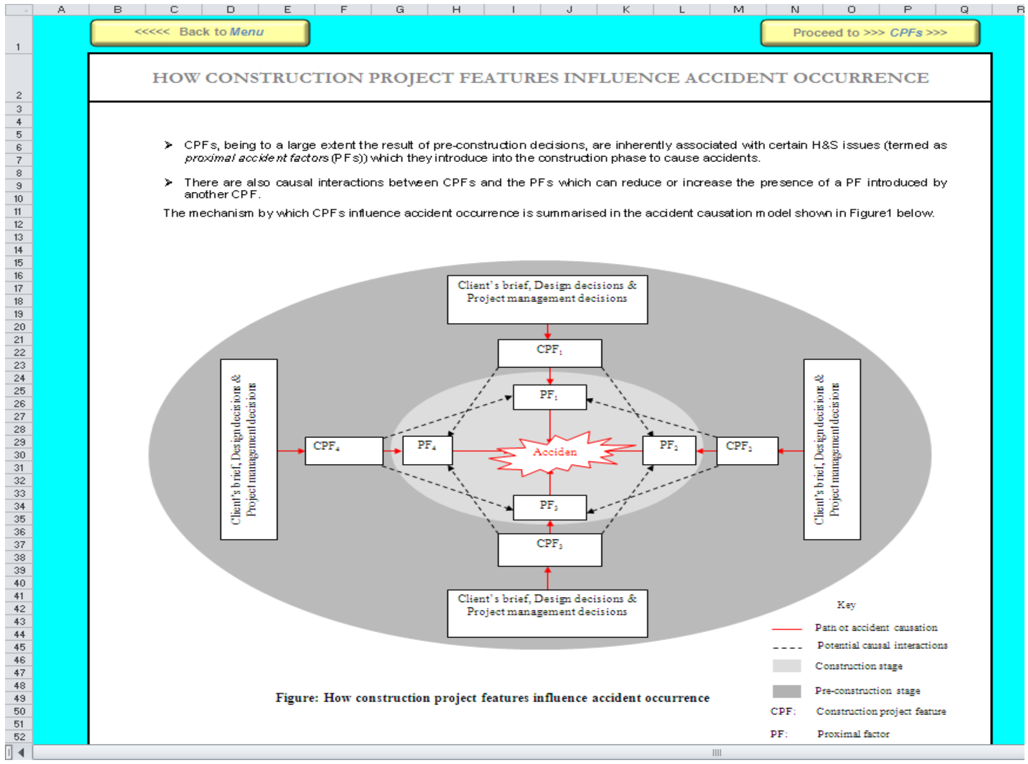



Figure 9.4: Worksheet for model of accident causation

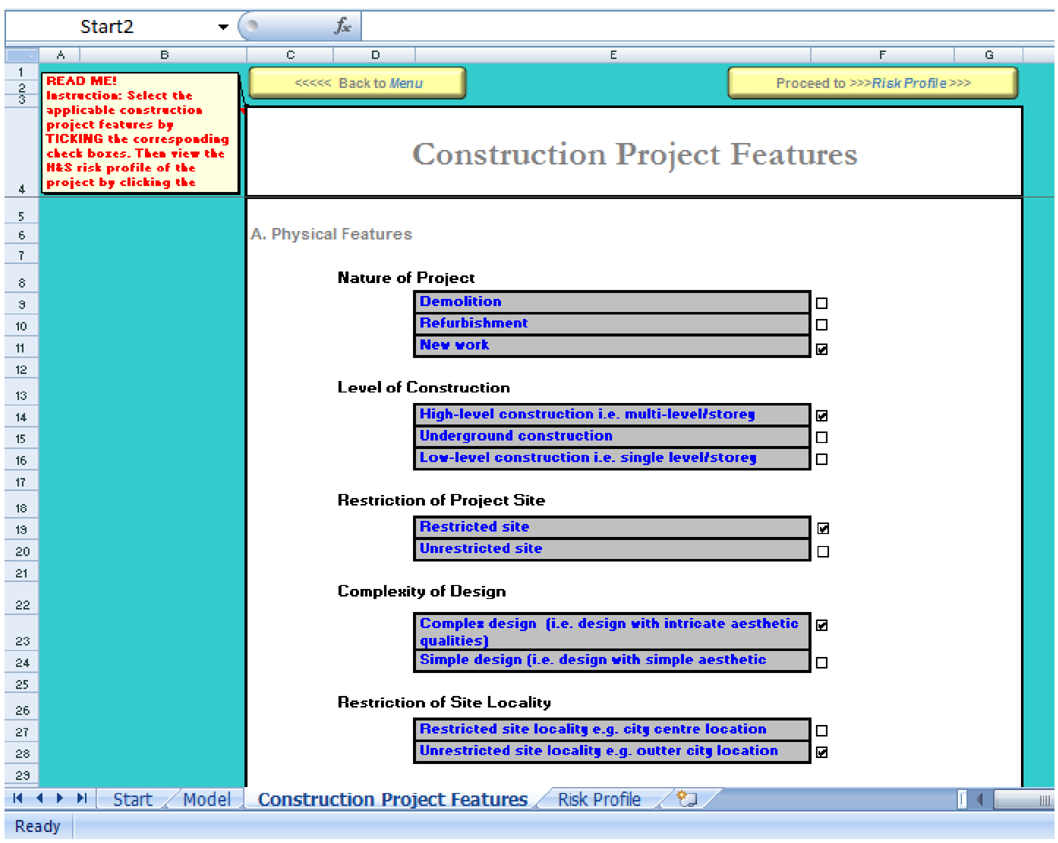



Figure 9.5: Worksheet for selection of CPFs

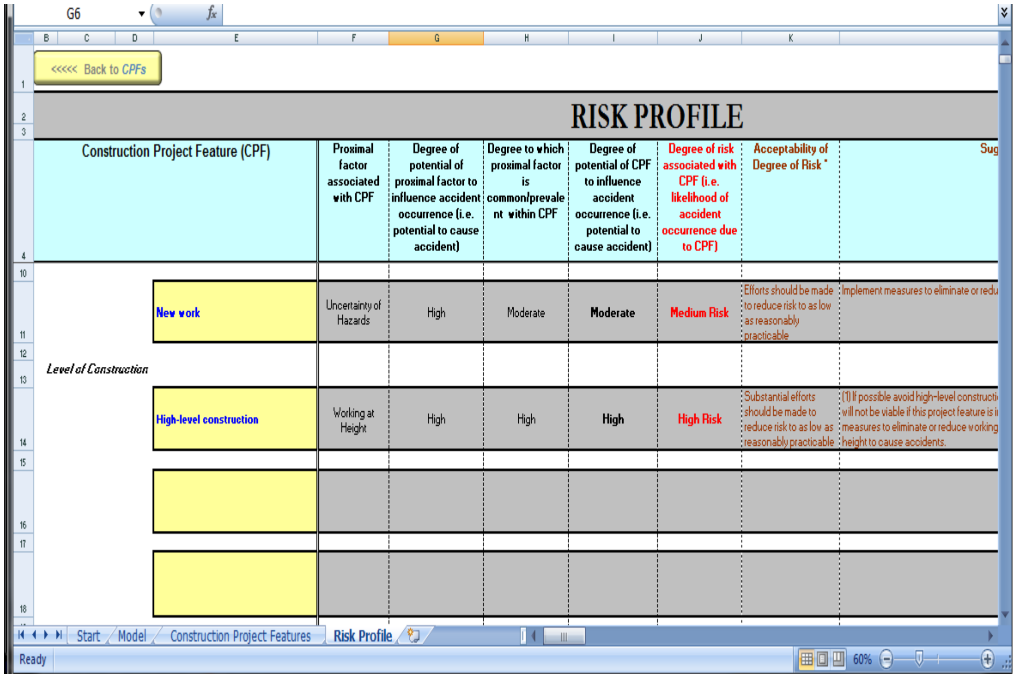



Figure 9.6: Worksheet for risk profile

The risk information provided by *CRiMT* has the potential of assisting pre-construction project participants (i.e. clients, designers, project managers and constructors) in managing the H&S risk introduced by CPFs through pre-construction H&S planning. This is because, it provides insight into the accident causal influence of CPFs which could inform: pre-construction decisions regarding CPFs; the prioritisation of risk control measures; and the devising and implementation of risk control measures to mitigate risk associated with CPFs from the pre-construction stage of projects.

However, in order to be able to make any firm and sound inference as to the potential utility of the risk information given by *CRiMT*, it was important that the research findings on which it is based are presented to practitioners for them to comment on their validity. In the same vein it is important that practitioners comment on the industrial relevance of the findings to pre-construction H&S planning. These point to the need to validate the research findings and also to verify their industrial relevance.

## 9.3 SUMMARY

Building on the assessment of the degree of potential of CPFs to influence accident occurrence, this chapter has presented the assessment of the degree of H&S risk associated with CPFs. CPFs are generally associated with *high risk* or *medium* risk implying that CPFs are generally associated with a high likelihood of accident occurrence or a medium likelihood of accident occurrence. Whereas with medium risk CPFs some risk control measures will suffice in mitigating risk, with high risk CPFs substantial measures are required. These findings have implications for pre-construction decision making regarding CPFs and also the prioritisation of risk control measures aimed at mitigating the accident causal influence of CPFs.

Building on the risk assessment, as a consolidation of the entire findings, this chapter has also presented a simple H&S risk management toolkit called *CRiMT*. This toolkit which is Microsoft Excel-based, provides two key sets of insight relating to: how CPFs influence accident occurrence; and the H&S risk profile of a project in relation to its features. These insights make the toolkit a viable H&S risk management instrument to pre-construction project participants in pre-construction H&S planning. Before any firm conclusions can be made as to the potential utility of the risk information given by the toolkit, it is important to ascertain the validity of the research findings on which it is based. Verification of the industrial relevance of the research findings as summarised by the toolkit is also required. The next chapter presents the validation of research findings and verification of their industrial relevance from practitioners' perspectives. Overall, this chapter completes the achievement of the fourth research objective and it has also addressed the fifth research objective.

# CHAPTER 10: RESEARCH VALIDATION

## 10.0 INTRODUCTION

The last two chapters presented the assessment of the degree of potential of CPFs to influence accident occurrence (i.e. potential to cause accident/harm) and their associated H&S risk (i.e. the likelihood of occurrence of accident/harm). A consolidation of the entire research findings in a simple H&S risk management toolkit was also presented. The extent to which the research findings (and hence the insight given by the toolkit) can be trusted however relies on the process of validation undertaken to confirm (or disconfirm) the research findings. This chapter presents the validation process that was undertaken in respect of this research. This chapter therefore addresses the sixth research objective.

## 10.1 RESEARCH VALIDATION PROCESS

Research findings serve among other purposes the provision of insight to implement interventions to influence a desired change or improvement. The validity of the findings of research regarding a phenomenon of interest is therefore important. Validity has been referred to as the best approximation to the truth (Cook and Campbell, 1979). Hair *et al.* (2010) also define validity as the degree to which a measure accurately represents what it is supposed to measure. Validity does not carry the same connotations in qualitative research as it does in quantitative research (Creswell, 2009). In terms of the qualitative inquiry, checks to ensure validity and reliability were presented in Section 6.2.1.3. The validation process discussed here thus focuses mainly on the quantitative inquiry. However, as was mentioned in Section 6.2.1.3, due to time-constraint, the member-checking aspect of demonstrating the validity of the qualitative findings was considered together with the validation of the quantitative findings. Brewer (2000) points out that validity is often not a question of the validity or invalidity of the research per se but rather the validity or invalidity of the statements, inferences and conclusions that are drawn from the results of empirical research. Validity is therefore a function of the design and implementation of research (Tuuli, 2009). The issue of validity is not without controversy regarding the types of validity that exist (cf. Kerlinger and Lee, 2000; Creswell, 2009; Garson, 2011). Garson (2011) therefore suggests that researchers be less concerned about defining and differentiating the types of validity but rather focus on addressing all the questions that can be asked about the validity of a piece of research. Following the suggestion of Shadish *et al.* (2002) in accordance with Cook and Campbell (1979), four questions relating to four areas of validity need to be addressed. These are:

1. Are the constructs valid?
2. Are the statistical conclusions valid?
3. Does the research demonstrate internal validity?
4. Does the research demonstrate external validity?

Having largely addressed the first two questions regarding construct validity and validity of statistical inference through the research process described so far especially in Chapter 7 (e.g. using scales adapted from past research; using a pilot survey to ascertain the clarity of the constructs and suitability of the scales; and using statistical procedures that were appropriate for their intended purpose), the searchlight is thrown on the external and internal validation of the research in this chapter.

## 10.2 EXTERNAL VALIDATION

External validity is the extent to which findings hold or generalise over variations in persons, settings, treatments, and outcomes (Shadish *et al.*, 2002; Fellows and Liu, 2008). According to

Brinberg and McGrath (1985), the essence of external validation is to gain confidence in the findings and what they mean. It is argued in Brinberg and McGrath (1985) that it is this process of validation that transforms research information into knowledge. There are three aspects of external validation: replication, convergence analysis and boundary search. These are considered in detail below.

### 10.2.1 Replication

Replication involves determining whether the set of findings can be reproduced when the same pathway (experimental, theoretical or empirical), the same set of instruments, and research strategy are used again (Brinberg and McGrath, 1985; Rosenthal and Rosnow, 1991). It is therefore a question of whether repeating a study will yield the original results. Other sources describe this as the test of reliability of the research (cf. Rosenthal and Rosnow, 1991; Kerlinger and Lee, 2000). Aside the logistical constraints in carrying out the same research again, an exact replication of any research is impracticable as no two occasions are exactly the same (Brinberg and McGrath, 1985; Rosenthal and Rosnow, 1991). External validation through replication is thus seldom used (Tuuli, 2009). Therefore for the above reasons, in this research like many before (cf. Ankrah, 2007; Anvuur, 2008; Tuuli, 2009) replication of the survey was not possible. It is however important to emphasise that the survey was designed and pre-tested to ensure that the data collected was reliable.

### 10.2.2 Convergence Analysis

Convergence analysis is the use of different methodologies or research strategies to study the same phenomenon (Denzin, 2009). Convergence is achieved when there is agreement of substantive outcomes derived from the use of different and independent models, methods, and/or occasions (Brinberg and McGrath, 1985). In this research the use of a mixed method strategy (although sequentially) to study the accident causal phenomenon of CPFs, to an extent revealed convergence between the qualitative findings and quantitative findings. This was demonstrated in Sections 8.2.1, 8.3.1, 8.6.1 and 9.1.1.

A further step in search for convergence which was also applied is referred to as *respondent validation* (Silverman, 2006). Creswell (2009) refers to this as *member checking*. Respondent validation involves research participants' verification of the tentative results of the research (cf. Silverman, 2006; Creswell, 2009). Where participants verify the tentative results of the research, this generates more confidence in the validity of the findings. This approach has been hailed as a characteristic of good research (Reason and Rowan, 1981). Respondent validation is common in construction management research and takes several forms (cf. Phua, 2004; Hari *et al.*, 2005; Ankrah, 2007; Anvuur, 2008; Tuuli, 2009). Whilst some researchers adopt follow up interviews with selected respondents (cf. Phua, 2004), others use focus groups (cf. Anvuur, 2008). Others have also adopted a follow-up questionnaire to respondents complimented by a summary report of the research findings (cf. Ahadzie, 2007; Ankrah, 2007; Tuuli, 2009). In this research the latter approach involving a research report and feedback form was adopted due to time and financial constraints. The feedback form was designed to achieve two objectives: (1) verification of the validity of the research findings; and (2) verification of the industrial relevance of the research findings (as summarised by the toolkit) to pre-construction H&S planning. A three page report of the key research findings including a feedback form (see Appendices E-1 and E-2) and the toolkit were sent to all the interview participants and the participants of the pilot and main survey who indicated that they were interested in the research findings or participating in a further phase of the research. In all a total of 197 participants were sent the report and feedback form. These included a construction H&S consultant who assisted in obtaining participants for the interview phase and indicated interest in receiving the research findings. The report, feedback form (in fillable Acrobat PDF) and the toolkit were mainly sent by email. One participant was contacted via post with the toolkit on a CD and a self-addressed free post envelope enclosed with the report and feedback form.

#### 10.2.2.1 Results of the Respondent Validation

Thirteen participants returned the feedback form (representing 6.5% response rate). It is important to highlight that some of the email contacts provided by the participants were not legible. This contributed to the attainment of the 6.5% response rate. The respondents included H&S managers, Construction managers, and Construction H&S consultants. The mean number of years of experience of the respondents in construction is 22.53 years. The responses to the various questions are tabulated in Appendix E-3 and summarised below.

Part of the responses in relation to the validity of the research findings are given in frequencies by Table 10.1. In response to whether CPFs influence accident through the introduction of H&S issues (which can be termed as proximal accident factors) into the construction phase to give rise to accidents, almost all the respondents (i.e. 12, representing 92.30%) responded in the affirmative. In response to whether there could be causal interactions between CPFs and proximal factors in the process of CPFs influencing accident occurrence, again almost all the respondents (i.e. 12, representing 92.30%) responded in the affirmative. These affirm the findings of the qualitative inquiry.

Regarding the assessment of the degree of potential of CPFs to influence accident occurrence the respondents generally agree that it is valid. Some of the remarks by the respondents are given below:

*"I agree - assessment is valid"* [Construction H&S Consultant]

*"Yes the factors reflect the situation that you are likely to find"* [H&S Manager]

Table 10.1: Feedback on validity of research findings

| **Item** | **Response** | | | | | |
|---|---|---|---|---|---|---|
| | **No response** | **Strongly Disagree** | **Disagree** | **Neutral** | **Agree** | **Strongly Agree** |
| 1. CPFs influence accident occurrence by their introduction of associated H&S issues (which can be termed as proximal factors) into the construction phase to give rise to accidents | 0% (0) | 0% (0) | 0% (0) | 7.69% (1) | 76.92% (10) | 15.38% (2) |
| 2. There can be causal interactions between CPFs and proximal accident factors | 0% (0) | 0% (0) | 0% (0) | 7.69% (1) | 84.62% (11) | 7.69% (1) |
| 3. The degree of potential of a CPF to influence accident occurrence is related to the extent to which its proximal factor(s) is common within it. | 0% (0) | 0% (0) | 0% (0) | 7.69% (1) | 76.92% (10) | 15.38% (2) |
| 4. The degree of potential of a CPF to influence accident occurrence is related to the degree of potential of its proximal factor(s) to influence accident occurrence | 0% (0) | 0% (0) | 0% (0) | 7.69% (1) | 76.92% (10) | 15.38% (2) |

Note: Total number of applicable respondents = 13. Outside bracket represents number of respondents

Similar to the assessment of the degree of potential of CPFs to influence accident occurrence, the respondents generally agree that the assessment of the degree of H&S risk associated with CPFs is valid. Some of the comments indicating this are given below:

*"I agree - assessment is valid"* [Construction H&S Consultant]

*"Valid"* [Construction Manager]

However, some respondents commented that the assessments are generic and do not take into account complex multi-causal relationships. Some of the comments in this regard are:

> *"These appear to be generalising specific and complex relationships."* [Construction Manager]
>
> *"Some good point are covered, but the multi-causal effect on the various issues on a construction site mean that the data is limited"* [H&S Manager]
>
> *"Again, it's a good effort but the multi-disciplinary nature of most construction sites and the sheer number of issues to be considered mean that the limitations of a short academic project would not allow all of the issues to be incorporated"* [H&S Manager]

These comments highlight the significance of complex multi-causal relationships which transpire in accident causation including the accident causal phenomenon of CPFs. Although the generic nature of the assessments does not invalidate the assessments, it points out a limitation of the assessment which can be addressed through further research. As discussed previously (see Section 5.3.1), an attempt to quantify the effects of causal interactions on the degree of potential of CPFs to influence accident occurrence and consequently their associated degree of H&S risk will be a herculean task if not impossible given the dynamic nature of construction. However a more realistic approach would be to identify possible causal interactions between CPFs and proximal factors so that such insight could be applied complementarily to the generic assessments.

Regarding the finding that the degree of potential of a CPF to influence accident occurrence is significantly related to the extent to which its proximal factor(s) is common within the CPF, almost all the respondents (i.e. 12, representing 92.30%) responded in the affirmative. In the same way, almost all the respondents (i.e. 12, representing 92.30%) either agree or strongly agree that the degree of potential of a CPF to influence accident occurrence is also significantly related to the potential of its proximal accident factor(s) to influence accident occurrence. These affirm the hypotheses.

As previously mentioned the validation also sought to verify the industrial relevance of the research findings as summarised by the toolkit. The respondents responded to a number of questions in relation to the risk profile displayed by the toolkit based on selected project features of a recent or on-going project which the respondents have worked on. The responses in connection to this are also given in Appendix E-3 and summarised by frequencies in Table 10.2.

In terms of how the risk profile given by the toolkit compared with the H&S challenges and risk experienced on the respondents' project, as shown by Part A of Table 10.2, the responses range from slightly similar to very similar with majority of the respondents (i.e. 9 representing 69.24%) indicating at least a fair similarity. This means that the information given by the toolkit (i.e. the research findings) reasonably reflects the actual H&S risk situations induced by CPFs on projects. This further reinforces the validity of the research findings and is indication that generally the information given by the toolkit has industrial relevance.

As part of verifying the industrial relevance of the research findings as summarised by the toolkit the respondents whose organisation's operations include property development (e.g. housing development), were asked to respond to two additional questions. These questions queried the usefulness of the information given by the toolkit in terms of informing/influencing pre-construction decisions that determine CPFs and also informing/influencing the pre-construction planning of design or project management solutions to control H&S risk posed by CPFs.

Table 10.2: Feedback on relevance of information given by toolkit to pre-construction H&S planning

| **Part A** | **Response** | | | | | |
|---|---|---|---|---|---|---|
| | **No response** | **Not similar** | **Slightly similar** | **Fairly similar** | **Similar** | **Very similar** |
| 1. Similarity of risk information to actual H&S challenges and risk experienced on the projects. | 15.38% (2) | 0% (0) | 15.38% (2) | 30.76% (4) | 23.10% (3) | 15.38% (2) |

Note: Total number of applicable respondents = 13. Outside bracket represents number of respondents

| **Part B** | **Response** | | | | | |
|---|---|---|---|---|---|---|
| | **No response** | **Not useful** | **Slightly useful** | **Fairly useful** | **Useful** | **Very Useful** |
| 2. Usefulness of information in terms of informing/influencing decisions that determine CPFs at pre-construction stage | 18.18% (2) | 0% (0) | 9.09% (1) | 36.36% (4) | 18.18% (2) | 18.18% (2) |
| 3. Usefulness of information in terms of informing/influencing the planning of design or project management solutions to control H&S risk posed by CPFs at pre-construction stage | 0% (0) | 0% (0) | 9.09% (1) | 45.45% (5) | 27.27% (3) | 18.18% (2) |

Note: Total number of applicable respondents = 11. Outside bracket represents number of respondents

The responses (given in Part B of Table 10.2) indicate that for 11 of the 13 respondents the nature of their organisations' operation partly involves making decisions which determine CPFs and also planning design or project management solutions to control H&S risk posed by CPFs. This include two H&S consultants whose role involves advising on such matters. From Table 10.2, a majority of the respondents (i.e. 8 out of the 11 representing 72.72%) indicated that the information given by the toolkit is at least fairly useful to informing/influencing decisions that determine CPFs. Again a majority of the respondents (i.e. 10 out of the 11 representing 90.91%) indicate that the information given by the toolkit is at least fairly useful to informing/influencing the planning of design or project management solutions to control

H&S risk posed by CPFs. These indicate that the information given by the toolkit is of industrial relevance to managing the H&S risk posed by CPFs through pre-construction H&S planning. Additional general comments given by the respondents further buttress this. One of these comments is:

*"Appropriate and relevant to this very complex industry."* [H&S Consultant].

There were however also comments pointing out limitations of the toolkit. One respondent opined that a hierarchical drop down list of CPFs would be better than the use of checkboxes. Another suggested that the suggested risk controls need to be reviewed to make the toolkit much more useful. As the suggested risk control measures given in the toolkit are broad based on the factors which influence the degree of potential of CPFs to influence, there is scope to expand on them to include specific examples of those broad measures. These suggested improvements could augment the user-friendliness of the toolkit and the industrial relevance of the risk information it provides in terms of pre-construction H&S planning.

Overall, it can be concluded from the responses that there is convergence between the views of the respondents and the findings of the qualitative and quantitative inquiries. The findings of the research are thus a sound reflection of the accident causal phenomenon of CPFs. There is however the need to further investigate the accident causal influence of CPFs to identify potential causal interactions between CPFs and proximal factors to complement the generic assessment of the degree of potential of CPFs to influence accident occurrence and their associated degree of H&S risk. There is also a reasonable indication that the information given by the toolkit is relevant to pre-construction H&S planning. There is however scope for improving the user-friendliness of the toolkit and more importantly the utility of the information it gives.

### 10.2.3 Boundary Search

Boundary search deals with the issue of the conditions under which the findings of a study will not hold (Brinberg and McGrath, 1985). Boundary search is often established over time through replications and convergence analysis to define the scope and boundaries of the findings of a particular research. It is therefore rare for researchers to go beyond replication and convergence analysis to deliberately establish the boundaries of their studies (Brinberg and McGrath, 1985). In this study, due to the time and financial constraints associated with completing a PhD it was not possible for the external validation to include boundary search. It is however acknowledged that there are some potential boundaries to the findings reported in this research, an example of which could be the country of study (i.e. the research context).

## 10.3 INTERNAL VALIDATION

Internal validity addresses how cause-effect relationships are free from sources of bias arising from, for example, research design (Garson, 2011). Although several sources emphasise the importance of good research design for achieving good internal validity (cf. Fellows and Liu, 2008; Garson, 2011), they however fall short of identifying appropriate procedures for checking whether indeed good internal validity has been achieved (Ankrah, 2007). Some researchers have however attempted to demonstrate internal validity by implementing several strategies. Notable among these attempts are the works of Proverbs (1998) and Xiao (2002) where they attempt to demonstrate internal validity through the search of convergence between research findings, published research and academic validation. The premise is that if convergence is demonstrated among these three, arguments about cause-effect relationships made in the research are valid. This strategy has been used in other construction management doctoral studies (cf. Ankrah, 2007; Tuuli, 2009) as a means to weigh the findings of these studies against published studies as well as to subject the study to expert scrutiny. Following the examples of these works, the following sections attempt to demonstrate convergence of the research findings with published work and how the findings pass academic scrutiny.

### 10.3.1 Convergence of Research Findings with Published Research

Maxwell (1992) refers to this type of convergence as theoretical validity which is the presence or absence of agreement within the community of inquirers about the descriptive or interpretive terms used. Convergence of the findings of this research and published research has been shown in several sections in the previous chapters by continually referring to the extant literature. To avoid repetition, references are only made here to the relevant sections. With the qualitative inquiry, convergence of the findings as to how CPFs influence accident occurrence with published research is shown in the results sections of the qualitative inquiry especially Section 7.1.3.

In relation to the quantitative findings, convergence with past research is also evident from the continual reference to the extant literature in the discussion sections of Chapters 8 and 9 (see Sections 8.2.1, 8.3.1, 8.4.1, 8.5.3 and 9.1.1). By making reference to literature in discussion of the results, the findings are found to be consistent with literature. Taken together, there is adequate convergence between the research findings and previous studies.

### 10.3.2 Academic Validation of Research Findings

Academic validation of the findings of this research takes the form of publication of papers in academic forums comprising, doctoral workshops, conferences, and journals where the papers are subjected to rigorous peer review. Peer review provides an opportunity for the methodologies, meanings and interpretation of research to be questioned by independent judges (Xiao, 2002). It is a process of critical inquiry which is meant to provide an informed, fair, reasonable and professional opinion about the merits of research work (Runeson and Loosemore, 1999). There are four possible outcomes of peer review. These are (i) acceptance without change; (ii) acceptance subject to minor changes; (iii) acceptance with major amendments; or (iv) rejection (Runeson and Loosemore, 1999). In all cases the peer review feedback outlining the basis of a decision, often raises issues which range from trivial to fundamental which can be incorporated in the research to improve its validity. In addition to the academic scrutiny provided by the peer review of papers, academic forums such as doctoral workshops and conferences allow members of the academic community of a discipline or research area to also scrutinize the methodologies, meanings and interpretation of a piece of research. This form of peer review also provides useful feedback which can be incorporated in the research to improve its validity.

So far eleven papers related to this research have been published and presented at international conferences and doctoral workshops. These are the:

- $1^{ST}$ International Conference on Infrastructure Development in Africa (ICIDA) (2012)
- Joint Association of Researchers in Construction Management (ARCOM) and Lean Construction Institute Doctoral Workshop (2011)
- West Africa Built Environment Research (WABER) Conference (2010, 2011)
- Association of Researchers in Construction Management (ARCOM) Doctoral Workshop (2009, 2010)
- CIB World Congress (2010)
- International Postgraduate Research Conference on the Built Environment (2010)
- Annual Association of Researchers in Construction Management (ARCOM) Conference (2010)
- Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (COBRA) (2010)

- CIB W099 Conference (2009)

A further four journal papers have also been published in highly rated journals. These journals are: Accident Analysis and Prevention; Management, Procurement and Law of the Institution of Civil Engineering; Journal of International Real Estate and Construction Studies; and Safety Science. The reference details of all the papers are given in Appendix A. The acceptance of these papers for publication in these forums after going through a rigorous peer review process provides confirmation that the research has met the high scholarly and academic standards required by these forums and is therefore scholarly and academically valid.

### 10.3.3 Convergence of Published Research and Academic Validation

Ankrah (2007) drawing from Proverbs (1998) argues that the acceptance of papers for publication (which by extension implies an acceptance of the published research cited in the papers) is a demonstration of convergence between published research and academic validation. This is built on the premise that the papers make arguments, interpretations and evaluate findings against published research and as such once the papers are accepted both the content of the papers and the published research cited in them are validated.

As shown by Table 10.3, a total of 564 published works are cited in the 15 papers which have been published. Although there is duplication of references in some of the papers as they address a similar subject, there are also many distinct and paper-specific references which support the findings reported in each paper. Based on the gross number of references, there is an average of 37 citations per paper. Following the precedence of Proverbs (1998), Ankrah (2007) and Tuuli (2009) it is argued that the acceptance of these papers for publication demonstrates that there is convergence between published research and academic validation.

Table 10.3: Citations in journal, conference and doctoral workshop papers

| No. | Authorship | Year | No. of Citations |
|---|---|---|---|
| 1 | *Manu et al.* | 2012 | 41 |
| 2 | *Manu et al.* | 2012 | 49 |
| 3 | *Manu et al.* | 2011 | 15 |
| 4 | *Manu et al.* | 2011 | 46 |
| 5 | *Manu et al.* | 2011 | 37 |
| 6 | *Manu et al.* | 2011 | 28 |
| 7 | *Manu et al.* | 2010 | 41 |
| 8 | *Manu et al.* | 2010 | 34 |
| 9 | *Manu et al.* | 2010 | 44 |
| 10 | *Manu et al.* | 2010 | 35 |
| 11 | *Manu et al.* | 2010 | 35 |
| 12 | *Manu et al.* | 2010 | 28 |
| 13 | *Manu et al.* | 2010 | 31 |
| 14 | *Manu et al.* | 2009 | 57 |
| 15 | *Manu et al.* | 2009 | 43 |
| | | **Total** | **564** |
| | | **Average** | **37.6** |

## 10.4 SUMMARY

This chapter has presented efforts to validate the findings of this research within the areas of external and internal validation. In the external validation, respondent validation or member checking was employed in convergence analysis. This involved 13 construction practitioners who commented on the validity of the research findings as well as the industrial relevance of the research findings as summarised by the H&S risk management toolkit. Generally the responses from the practitioners concur with the research findings indicating that the findings are valid and accurately represent the accident causal influence of CPFs. The responses from the practitioners also generally indicate that the findings of the research as summarised by the H&S risk management toolkit are of relevance to the management of the accident causal influence of CPFs. The practitioners however also expressed views which point to the need for further studies into the accident causal influence of CPFs to complement the research findings presented here. There were also views which point to some scope to further augment the industrial utility of the information given by the H&S risk management toolkit.

In the internal validation, convergence between research findings, published research, and academic validation was sought. Among these three aspects, convergence has been achieved indicating agreement between the research findings and the established knowledge.

On the basis of the validated research findings, it is appropriate to finally draw conclusions on the entire research and make relevant recommendations. This is addressed by the next chapter. Overall, this chapter has addressed the sixth research objective.

# CHAPTER 11: CONCLUSIONS AND RECOMMENDATIONS

## 11.0 INTRODUCTION

The research has explored the mechanism by which CPFs influence accident occurrence, their degree of potential to influence accident occurrence and their associated H&S risk. This has led to a number of research findings which have been consolidated by the development of a simple H&S risk management toolkit. This chapter summarises the entire research and then presents the main conclusions, contribution to knowledge, and the limitations of the research. These are followed by some consideration of potential industrial implications of the research findings particularly in relation to pre-construction H&S planning, and also some recommendations for further research.

## 11.1 SUMMARY OF THE RESEARCH

In chapter 1 of this thesis, the background to this research was presented. The main issue revealed was that, in reporting causal factors in construction accidents construction H&S studies have mainly made passing reference to the accident causal influence of CPFs which emanate from the pre-construction stage of project procurement, despite the established significance of underlying causal factors to accident causation. As a result, detailed insight regarding how CPFs influence accident occurrence, their degree of potential to influence accident occurrence and their degree of associated H&S risk remain elusive in the extant H&S literature. This informed the posing of three research questions:

- How do CPFs influence accident occurrence?
- What is the degree of potential of CPFs to influence accident occurrence? and;
- What is the degree of H&S risk associated with CPFs?

To answer these questions, the research aimed to empirically investigate the mechanism by which CPFs influence accident occurrence and assess their degree of potential to influence accident occurrence and their associated H&S risk. To achieve these aims, 7 research objectives were put forward. The review of research objectives below outlines how these objectives were achieved.

### 11.1.1 Review of Research Objectives

***Objective 1:*** *Undertake a critical review of the state of H&S in the UK construction industry highlighting the H&S performance, challenges, some improvement efforts and the accident causal influence of CPFs.*

This objective is addressed in Chapters 2 and 3. A review of H&S literature on the UK construction industry revealed that the industry continues to have a poor H&S record marked by several deaths, injuries, and illnesses being reported each year. The review also revealed that the construction industry by its nature presents difficulties to improving the H&S performance. The highly fragmented nature of the industry; the inadequate integration among the supply chain members; the large number of micro and small construction companies; and the growing number of migrant workers within the industry make achieving H&S improvement challenging. The huge cost associated with the tragedies reported each year in the industry mean that change is inevitable and to that end several improvement efforts have been made and continue to be made. Notably, among these efforts are the introduction of H&S legislation; industry wide and H&S specific initiatives such as the Revitalising H&S Initiative; and research in construction H&S examining factors responsible for accidents from which work-related injuries and illnesses emanate.

Particularly referring to H&S studies, the literature review revealed that both within and outside of the UK construction industry, the vast majority of accident causation studies have focussed on proximate/site-based accident causes. Even where underlying causes have been reported some of those causes are still site-based causal factors and do not extend to the underlying causes which have their roots in the early stages of construction project procurement. Among the very few studies which have looked at underlying causes, it has been emphasised that there is the need to pay attention to root causal factors in order to prevent accidents on a long-term and sustainable basis (i.e. to have sustained H&S improvement). The need to pay attention to underlying causal factors is also reinforced by the fact that the pre-construction stage from which they emanate offers project participants the greatest opportunity to influence H&S on projects. Despite the established significance of underlying/root accident causal factors to H&S, it was revealed that not much by way of research has focussed on the underlying accident causal role of construction project features (CPFs) which are organisational, physical and operational attributes of construction projects which emanate from the pre-construction stage of projects. As a result of the dearth of research focus on the accident causal influence of CPFs, detailed insight as to how CPFs influence accident occurrence, their degree of potential to influence accident occurrence and their associated H&S risk remains elusive and hence represents a knowledge gap in the extant H&S literature which needs to be explored. Completion of this comprehensive review, the findings of which reinforced the case for undertaking this research represented an achievement of the first research objective.

***Objective 2:*** *Undertake a critical review of H&S risk management with the aim of identifying a suitable method for evaluating the H&S risk associated with CPFs.*

This objective is addressed in Chapter 4. As a key step towards bridging the identified knowledge gaps, an in-depth review of H&S risk management literature was undertaken to obtain a suitable approach for evaluating the H&S risk associated with CPFs. The review revealed several definitions and three main methods of evaluating H&S risk: qualitative; semi-quantitative; and quantitative. Given the context of the research (i.e. UK) the UK HSE definition of risk was adopted. The review revealed that a semi-quantitative method of risk evaluation is more appropriate for evaluating the H&S risk associated with CPFs as the qualitative approach mainly prioritises hazards and gives no indication of degree of risk, and the quantitative approach requires extensive historical and numerical data, a condition which cannot be met due to limitations in accident records. In terms of using the semi-quantitative approach, involving the adoption of a risk combination matrix, the risk expression: risk = hazard x exposure, was found to be suitable for evaluating the degree of H&S risk associated with CPFs taking into account their degree of potential to influence accident occurrence. This expression was thus adapted for use in a risk combination matrix. The degree of H&S risk associated with a CPF (Rk) was thus expressed mathematically as a product of the degree of potential of the CPF to influence accident occurrence and exposure of workforce. The identification of the semi-quantitative method of risk evaluation and the adaptation of the mathematical risk expression for assessing the degree of H&S risk associated with CPFs represented an achievement of the second research objective.

***Objective 3:*** *Develop a conceptual model of the accident causal influence of CPFs and to develop a measurement framework for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk.*

This objective is addressed in Chapter 5. As accident causation models are often used in explaining how accidents occur, a critique of accident causation models was undertaken with the intent of obtaining insight into how CPFs influence accident occurrence. From this critique, it was found that due to the underlying nature of the accident causal influence of CPFs, systems models of accident causation offer the best scope for explaining how CPFs influence accident occurrence as the systems models take a broader view of accident occurrence by considering underlying causal factors responsible for immediate/proximate accident causes and the complex inter-relationships among them. By drawing on the systems view of accident causation, a conceptual model of how CPFs influence accident occurrence was thus developed. Also by drawing on the adapted risk expression for evaluating the degree of H&S risk associated with CPFs, and by a critical examination of the components of the expression, a measurement framework was put forward to provide an overall coherent guide for the systematic assessment of the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. The framework also detailed two factors which have been suggested to influence the degree of potential of CPFs to influence accident occurrence. Two hypotheses were thus posited to verify the influence of these factors. The development of the conceptual model and measurement framework thus represented an achievement of the third research objective.

***Objective 4:*** *Empirically verify the conceptual model and develop an instrument to collect and analyse data to determine the degree of potential of CPFs to influence accident occurrence and their associated H&S risk.*

This is addressed from Chapters 6 to 9. Building on the achievement of the third objective, the need to both empirically verify the developed conceptual model and also implement the measurement framework dictated the adoption of a mixed method research design underpinned by an overall positivist paradigm. The mixed method design comprised a first phase of qualitative inquiry followed by a quantitative inquiry. The qualitative inquiry provided empirical verification of the conceptual model by indicating that CPFs influence accident occurrence through the inherent introduction of certain associated H&S issues (which can be termed as proximal factors) into the construction phase of projects to give rise to accidents. There are also causal interactions which transpire between CPFs and the proximal factors they introduce which can reduce or increase the presence of proximal factors. These finding of the qualitative inquiry addressed the research question relating to how CPFs influence accident occurrence.

Drawing on the findings of the qualitative inquiry and the measurement framework, a questionnaire was designed to elicit the views of practitioners in construction management roles in construction firms to enable the assessment of the degree of potential of CPFs to influence accident occurrence. Through the questionnaire, the practitioners provided expert judgement on three main issues: (1) the degree of potential of CPFs to influence accident occurrence; (2) the degree of potential of proximal factors associated with particular CPFs to influence accident occurrence; and (3) the extent to which proximal factors are common/prevalent within their associated CPFs. Information on the last two issues were used in testing the proposed hypotheses that the degree of potential of a CPF to influence accident occurrence is related to two factors: the degree of potential of its proximal factor(s) to influence accident occurrence; and the extent to which the proximal factor(s) is common/prevalent within the CPF.

Following a successful pilot of the questionnaire, a main survey was undertaken on a randomly selected sample of contractors listed in the UK Kompass online directory with the target source of data being practitioners in construction management roles within construction firms. All together the survey yielded 187 responses representing 18.7% response rate. Statistical analysis conducted on the data included descriptive statistics, inter-rater agreement tests, and correlation and regression analysis. The descriptive statistics provided a thorough understanding of the respondents' expertise and experience which was shown to be respectable and therefore meant the findings drawn from their responses will be a credible reflection of the accident causal influence of CPFs. The descriptive statistics, in particular arithmetic mean, was used to aggregate the individual responses of the respondents to have single representative measures in relation to the 3 main issues addressed by the questionnaire. In order for the mean measures to be interpreted with confidence an inter-rater agreement test was then undertaken to confirm that there is significant agreement among the respondents in terms of their judgements on the issues being assessed. Finally, correlation and regression analysis were undertaken for the test of hypotheses. Building on the assessment of the degree of potential of CPFs to influence accident occurrence, a risk combination matrix incorporating the adapted H&S risk expression was used to assess the degree of H&S associated with CPFs. The findings of the quantitative assessments addressed the research questions relating to the degree of potential of CPFs to influence accident occurrence and their associated H&S risk. These findings are briefly presented below.

Concerning the degree of potential of CPFs to influence accident occurrence, it was found that CPFs generally have a *moderate* or *high* potential to influence accident occurrence implying that CPFs have a *fair* potential to cause harm or a *severe* potential to cause harm in respect of the H&S of workers. Not surprisingly, amongst the CPFs which have a high potential are demolition, refurbishment, tight project duration, complex design, underground construction, high-level construction, multi-layer subcontracting, restricted site and restricted site locality. Amongst the CPFs which have a moderate potential are new work, unrestricted site locality, unrestricted site, low-level construction, adequate project duration, single-layer subcontracting, and simple design. Surprisingly, procurement methods, in particular design and build, partnering, traditional procurement, and management contracting are all assessed as having a *moderate potential* despite reports in the extant literature and results from the qualitative inquiry which suggest that design and build and partnering improve H&S as they allow for collaborative working among project team members and hence fostering better H&S management than traditional procurement and management contracting. Another surprising finding which also confounds extant literature and results from the qualitative inquiry is that pre-assembly construction and traditional construction are both considered as having a *moderate potential* despite the reported H&S benefits of pre-assembly construction.

From the test of hypotheses, it was confirmed that the degree of potential of a CPF to influence accident occurrence is indeed influenced by: the extent to which its proximal factor(s) is common/prevalent within the CPF; and the degree of potential of the proximal factor(s) to influence accident occurrence. These findings provide some scope for explaining the surprising assessment in relation to the procurement methods and the methods of construction.

Concerning, the degree of H&S risk associated with CPFs, it was found that where CPFs apply on a project, they are generally associated with *medium risk* or *high risk*, implying that CPFs are associated with a medium likelihood of accident occurrence or a high likelihood of accident occurrence where they apply on projects. Where a CPF does not apply on a project it poses no risk as the workforce will not be exposed to its potential to influence accident occurrence. Not surprisingly, these findings mirror the findings of the assessment of degree of potential of CPFs to influence accident occurrence in that the CPFs which have a moderate potential are associated with medium H&S risk and those having a high potential are associated with high risk. In terms of acceptability of H&S risk, the findings imply that the H&S risk associated with CPFs is generally not acceptable. However, whereas with medium risk CPFs some risk control measures will suffice in mitigating risk, with high risk CPFs substantial measures are required. The empirical verification of the conceptual model and subsequent quantitative assessment of the degree of potential of CPFs to influence accident occurrence and their associated H&S risk represented an achievement of the fourth research objective.

***Objective 5:*** *Consolidate the findings of the research by developing a simple H&S risk management toolkit which focuses on the accident causal influence of CPFs.*

This is addressed in Chapter 9. The findings from both the qualitative and quantitative inquiries addressing the research questions were summarised and merged together in the form of a simple Microsoft Excel-based H&S risk management toolkit nick named, "*CRiMT*" (i.e. acronym for CPFs risk management toolkit). *CRiMT* provides in a unified succinct format the entire findings of the research. It provides two key sets of information: how CPFs influence accident occurrence; and the H&S risk profile of a construction project in relation to its features. It serves as an electronic repository which allows the findings of the research to be stored, retrieved and shared with ease. In line with the emphasis on positively influencing H&S from the early stages of project procurement, *CRiMT* could potentially assist pre-construction project participants in managing the accident causal influence of CPFs through pre-construction H&S planning. The development of *CRiMT* thus represented the achievement of the fifth research objective.

***Objective 6:*** *Validate the research findings and evaluate their industrial relevance to pre-construction H&S planning from practitioners' perspective.*

This is addressed in Chapter 10. The validation of the research was within two domains: external validation and internal validation. In the external validation, respondent validation was employed in convergence analysis. Thirteen construction practitioners commented on the validity of the research findings as well as the industrial relevance of the research findings as summarised by the H&S risk management toolkit. The responses from the practitioners concur with the research findings indicating that the findings are valid and accurately represent the accident causal influence of CPFs. The responses also indicate that the findings of the research as summarised by the toolkit are of relevance to the management of the accident causal influence of CPFs from the perspective of pre-construction H&S planning. The practitioners however also expressed views which point to the need for further studies into the accident causal influence of CPFs to complement this research. There were also similar views which point to a scope to further augment the industrial utility of the information given by the toolkit.

In the internal validation, convergence between research findings, published research, and academic validation was sought. Among these three aspects, convergence was demonstrated indicating agreement between the research findings and the established knowledge.

***Objective 7:*** *Draw conclusions from the findings of the study to provide a basis for proposing implications for H&S practice and recommendations for further research.*

The achievement of this objective is addressed by this chapter as given in the following sections.

## 11.2 CONCLUSIONS OF THE RESEARCH

The main conclusions drawn from the research are that:

- CPFs, being to a large extent the result of pre-construction decisions, influence accident occurrence by their inherent introduction of certain associated H&S issues (which can be termed as *proximal accident factors*) into the construction phase of projects which give rise to accidents. There are also causal interactions between CPFs and the proximal factors which can reduce or increase the presence of proximal factors.
- CPFs have varying degrees of potential to influence accident occurrence which can generally be *high* or *moderate* implying that CPFs have a fair potential to cause harm or a severe potential to cause harm in respect of the H&S of workers.
- The degree of potential of a CPF to influence accident occurrence is influenced by: the extent to which its proximal factor(s) is common/prevalent within the CPF; and the degree of potential of the proximal factor(s) to influence accident occurrence.
- CPFs have varying degrees of H&S risk associated with them which can generally be *medium risk* or *high risk*, implying that CPFs are generally associated with a medium likelihood of accident occurrence or a high likelihood of accident occurrence where they apply on projects. In terms of acceptability of H&S risk, the H&S risk associated with CPFs is unacceptable. However, whereas with medium risk CPFs some risk control measures will suffice in mitigating risk, with high risk CPFs substantial measures are required.

These conclusions provide answers to the research questions posed to interrogate the accident causal influence of CPFs. In summary, the accident causal influence of CPFs cannot be ignored in efforts to improve the H&S situation of the UK construction industry, and this further emphasises the importance of the early planning of H&S in project delivery.

## 11.3 CONTRIBUTION TO KNOWLEDGE

This research has provided new insight into construction accident causation from the perspective of the accident causal role of CPFs, revealing how CPFs contribute to accident causation, their degree of potential to influence accident occurrence, and the degree of H&S risk associated with CPFs.

Regarding how CPFs influence accident occurrence, this study has shown that CPFs, originating from pre-construction decisions by clients and their design and project management teams, influence accident occurrence by their introduction of certain associated H&S issues (which can be termed as *proximal accident factors*) into the construction phase of projects to give rise to accidents. In addition to this path of causation, the process by which CPFs influence accident occurrence could be marked by causal interactions between CPFs and proximal factors which could reduce or worsen the presence of the proximal factors they introduce. The research has thus shown that the mechanism by which CPFs influence accident occurrence aligns with the systems view of accident causation as it exhibits two key features: the path of accident causation from underlying causal factors through induced immediate/proximate causes to accident events; and causal interactions among these causal factors. As a contribution to previous construction accident causation studies which have examined underlying causal factors, this study has thus put the spotlight on CPFs from amongst underlying causes of construction accidents and it explains how various CPFs acting collectively on a project can influence the occurrence of accidents on the project.

Regarding the degree of potential of CPFs to influence accident occurrence and their associated H&S risk, this research has bridged the knowledge gap in the literature by providing assessments which go beyond simple comparative assessments (i.e. greater or lesser potential to influence accident occurrence/H&S risk) among CPFs of the same kind. The assessments given by this study indicate the individual extent of the potential of CPFs to influence accident occurrence as well as their associated H&S risk which are more insightful than the simple comparative assessment. CPFs generally have a *moderate* or *high* potential to influence accident occurrence and where they apply on projects, they are associated with medium risk (i.e. medium likelihood of accident occurrence) requiring some risk control measures, or they are associated with high risk (i.e. high likelihood of accident occurrence) requiring substantial risk control measures. The study has also provided empirical evidence that the degree of potential of a CPF to influence accident occurrence (and consequently their associated H&S risk) is influenced by: the extent to which its proximal factor(s) is common/prevalent within the CPF; and the degree of potential of the proximal factor(s) to influence accident occurrence.

As a consolidation of the entire research findings, *CRiMT* which is a H&S risk management toolkit focussing on the accident causal influence of CPFs has also been developed. *CRiMT* serves as a knowledge base from which H&S risk information regarding CPFs can be tapped.

Beyond the specific outcomes of the research discussed above, this research has contributed to construction accident causation research, majority of which have focussed on proximate causal factors, by the specific attention that has been accorded to deep underlying causal factors which derive from the early stages of project procurement. Given the difficulty in investigating such underlying causal factors due to their remoteness from accident events and the latent nature of their influence, the approach that has been adopted in this research for assessing the degree of potential of CPFs to influence accident occurrence and their associated H&S risk, could be adopted or adapted by other researchers in studying other underlying causal factors.

Overall, considering the fact that the opportune period to influence safety on projects is the pre-construction stage this research provides insight which could potentially lead to a further step towards achieving a safer construction industry.

As a result of the research undertaken, fifteen technical papers have been published in refereed international construction and H&S journals, conference and doctoral workshop proceedings. Full bibliographic details of these papers are provided in Appendix A.

## 11.4 LIMITATIONS OF THE RESEARCH

As acknowledged by this study, construction accident causation is complex and multi-faceted, involving several inter-related accident causal factors (proximate and root) which generally merit attention in order to have a holistic approach to accident prevention. This means that mitigating the accident causal influence of CPFs alone will not automatically yield accident-free projects. That having been said, the accident causal influence of CPFs can however not be underestimated or ignored given the associated dire H&S consequences.

Aside their negative influence in causing accidents, a CPF may also have a mitigating (in other words a positive) influence in accident occurrence which could take the form of causal interactions between a CPF and the proximal factors introduced by another CPF. However, the potential of CPFs to influence accident occurrence was taken in the context of this study as their potential to cause accident, and due to the H&S focus of this research (i.e. protection of workers from injury and ill-health) this was limited to their potential to cause harm in respect of the H&S of workers. As indicated in previous discussions, the causal interactions that could transpire between CPFs and the proximal factors introduced by other CPFs epitomise the complex and multi-faceted nature of construction accident causation which can be further complicated by the dynamic nature of construction. As was acknowledged, the degree of potential of CPFs to influence accident occurrence and consequently their associated H&S risk can be influenced by these complex causal interactions. However, the assessments given by this study are generic representing the individual/independent effects of each CPF which do not take into account the effects of possible causal interactions. As was argued, an attempt to measure/assess some kind of a “resultant” degree of potential of CPFs to influence accident occurrence and their associated H&S risk which takes into account all possible dynamic causal interactions will be a herculean task if not impossible, hence the adoption of a pragmatic approach in this study. However, beyond this study it will be useful to complement the generic individual/independent assessments of CPFs by deeper knowledge of possible causal interactions even if this does not include measurement of their resultant effects. Therefore, although the assessments given by this study are valid, further studies are required to make up for this limitation.

The findings of this study have been based on the professional judgement of construction professionals and as such one could argue that the findings may not be a true reflection of the accident causal influence of CPFs. A counter argument however is that the judgement of the professionals are shaped by their construction expertise and experience which was shown to be respectable and as such their response and hence the eventual research findings are a credible reflection of the accident causal influence of CPFs. The convergence between aspects of the qualitative and quantitative inquiries and the validation further reinforce the credibility of the research findings. In addition, it was not possible to ascertain whether or not all the respondents answered the questions with honesty based on their industrial experience. Thus if the respondents failed to answer the questions honestly then the results may not be a true reflection of the accident causal influence of CPFs. However, the application of multiple research methods and the validation of the research findings helped to obviate the potential biases thereby resulting in credible findings. Also, given that the focus of the empirical aspects of this research was entirely on the UK, it is plausible that there may be differences in the findings if this study is replicated in another context. This aspect is recommended as a potential area for further research.

Another limitation of the research is that although the research design adopted for this study was adequate in achieving the research aim, the research has given a snapshot of the accident causal influence of CPFs as it did not solely focus on delving deep into any particular CPF. Doing this, can reveal further insights beyond that given by this research and this is recommended for further studies.

Finally, although the 5-point scales used for the assessments are commonly used in construction management research, and has also been applied in similar construction accident causation studies, it may be that the scales were not wide enough in capturing subtle differences in the degree of potential of the CPFs and proximal factors to influence accident occurrence and also the extent to which the proximal factors are common/prevalent within CPFs. Perhaps a wider scale, for instance a 7-point scale (in the order of: low, low-medium, medium, high-medium, low-high, high, and very high) may have been slightly more sensitive to subtle differences. This may have partly accounted for some of the surprising results. The convergence between the quantitative findings and the results of the respondent validation however gives credence to the quantitative findings.

## 11.5 INDUSTRIAL IMPLICATIONS OF THE FINDINGS

The insight given by this study has implications for managing the accident causal influence of CPFs and these are considered below.

- Pre-construction project participants could on the basis of the insight into the degree of potential of CPFs to influence accident occurrence or their associated H&S risk make better considered decisions at the early stages of project procurement when considering alternative project features. As pre-construction project participants are sometimes faced with constraints, high risk CPFs may be inevitable. In such instances the insight into the H&S risk associated with CPFs could inform the prioritising of risk control measures in terms of resource allocation. The findings on the degree of potential of CPFs to influence accident occurrence could also provide the necessary stimulus for the industry as a whole to place greater emphasis on addressing CPFs which have a high potential to influence accident occurrence while giving due attention to CPFs which have moderate potential to influence accident occurrence. For example, a tight project timescale which has been shown to have a high potential to influence accident occurrence and has been suggested to be commonplace within the industry despite relevant legal requirements should attract the attention of industry stakeholders.
- The factors which have been shown to influence the degree of potential of CPFs to influence accident occurrence, provide evidence based justification for devising and implementing measures for mitigating the degree of potential of CPFs to influence accident occurrence and consequently their associated H&S risk.

- As the knowledge of how accidents occur is useful in developing accident controls, the understanding into how CPFs influence accident occurrence could form the basis of devising control measures to mitigate the accident causal influence of CPFs. For instance measures could be devised to remove proximal factors introduced by CPFs. The knowledge of the potential existence of causal interactions between CPFs and proximal factors could also be a basis for considering CPFs which can mitigate the causal influence of other CPFs especially where some CPFs are inevitable. Also the understanding into how CPFs influence accident occurrence could facilitate accident investigation in terms of probing the contribution of CPFs and hence the contribution of pre-construction project participants.
- Referring to the intriguing finding in relation to the degree of potential of the investigated procurement methods to influence accident occurrence, this research has provided evidence that it can be due to the similar extent of fragmentation of project team (i.e. moderate) within the procurement methods which was found by the research. This similar extent of fragmentation of project team within the procurement methods affirms the findings of other studies that the adoption of integrated procurement approaches does not automatically yield enhanced collaborative working among members of the project team. In view of this, where integrated procurement approaches are used, efforts still need to be made to overcome adversarial working relationships so that their espoused benefits (which encompass H&S) could be realised. Also, referring to the intriguing finding in relation to the degree of potential of pre-assembly construction and traditional construction to influence accident occurrence (i.e. both generally perceived as having moderate potential), this research provides some indication that it is in part due to safer manual handling techniques within the industry as manual handling is considered to have a moderate potential to influence accident

occurrence just as mechanical handling which has been known to be safer. In view of this, it is reasonable to point that continual sustained training on safe manual handling techniques will be of immense benefit. The HSE is playing a vital role in this regard through the amended Manual Handling Operations Regulations 1992 (amended 2002) and the publication of industry guidance such as INDG143(rev2) (titled, "Getting to grips with manual handling: A short guide") which has recently been revised.

- As *CRiMT* (i.e. the developed H&S toolkit) is a unification of the entire research findings, it thus offers pre-construction project participants a reference point/repository from which the findings offered by this research could be tapped for managing the accident causal influence of CPFs. The H&S risk information given by *CRiMT* could thus assist project participants in managing the H&S risk posed by CPFs during pre-construction H&S planning and decision-making which determines CPFs.

## 11.6 RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the research findings and the limitations that have been noted, the following recommendations are put forward for future research in this domain:

- To complement the assessment of the degree of potential of CPFs to influence accident occurrence, it is important that studies be conducted into the potential causal interactions between CPFs and proximal factors. As such an inquiry will heavily rely on the expertise of experienced construction practitioners, a Delphi method could be used. This method is particularly useful when there is incomplete knowledge about a problem or phenomena and also where problems do not lend themselves to precise analytical techniques but rather could benefit from the subjective judgments of individuals on a collective basis by focusing their collective human intelligence on the problem at hand.

- This study provides a snapshot of the accident causal influence of CPFs and as such there is scope for further research focusing on each of the CPFs investigated in this study. In-depth qualitative research approaches such as case-studies are preferable for this sort of study. Indeed such inquiry into each of the CPFs could provide insight on practical measures for controlling the H&S risk associated with CPFs which could be incorporated in the suggested risk control measures given in the H&S risk management toolkit.

## 11.7 SUMMARY

This chapter has provided a review of the original research objectives and the extent to which they were achieved. The main conclusions addressing the research aim and hence the research questions have been presented and the limitations of the research have been acknowledged. Implications of the research for industrial H&S practice and recommendations for further research have also been proposed.

In summary, given the established significance of underlying causal factors to construction H&S, the accident causal influence of CPFs cannot be underestimated or ignored in the pursuit of H&S improvement in the construction industry. Considering the fact that the opportune period to influence safety on projects is the pre-construction stage the insight provided by this research presents an early opportunity for pre-construction project participants, and indeed construction phase participants, to positively influence H&S on projects by effectively managing the accident causal influence of CPFs through pre-construction H&S planning and decision-making which determines CPFs.

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# APPENDICES

## Appendix A: Publications

**Publications**

***Refereed Journal Papers***

**Manu, P.**, Ankrah, N., Proverbs, D. and Suresh, S. (2012) Investigating the multi-causal and complex nature of the accident causal influence of construction project features. *Accident Analysis and Prevention*, 48, 126-133.

**Manu, P**., Ankrah, N., Proverbs, D. and Suresh, S. (2011) The adverse health and safety influence of subcontracting. ICE Proceedings- Management, Procurement and Law, 164(4), pp. 169-171.

**Manu, P.**, Ankrah, N., Proverbs, D. and Suresh, S. (2011) The influence of pre-construction decisions on accident causation- a causal model. *Journal of International Real Estate and Construction Studies*, 1(1), pp. 53-70.

***Melrose, A., Hampton, P. and **Manu, P**. (2011) Safety at sports stadia. *Procedia Engineering*, 14, pp. 2205–2211. [Invited paper as part of the Proceedings of Twelfth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-12), 26-28 January 2011, Hong Kong].

**Manu, P.**, Ankrah, N., Proverbs, D. and Suresh, S. (2010) An approach for determining the extent of contribution of construction project features to accident causation. *Safety Science*, 48 (6), pp. 687-692.

***Refereed Conference and Doctoral Workshop Papers***

**Manu, P**., Proverbs, D., Suresh, S., Ahadzie, D.K., and Manu, E. (2012) A preliminary investigation into the potential of construction project features to influence accident occurrence. In: *Proceedings of the 1st International Conference on Infrastructure Development in Africa (ICIDA 2012)*, 22nd – 24th March 2012, Kumasi, Ghana.

**Manu, P.**, Ankrah, N., Proverbs, D. and Suresh, S. (2011) Investigating the accident causal influence of construction project features: An effort towards improving construction project delivery. In: *Proceedings of Joint Association of Researchers in Construction Management (ARCOM) and Lean Construction Institute Doctoral Workshop*, 2nd March 2011, University of Northumbria, UK.

**Manu, P.**, Ankrah, N., Proverbs, D., Suresh, S., and Adukpo, E. (2011) Managing the adverse health and safety impact of subcontracting: Findings of a qualitative inquiry. In: Laryea, S., Leiringer, R., Hughes, W. (Eds.), *Proceedings of West Africa Built Environment Research (WABER) Conference*, 19-21 July 2011, Accra, Ghana.

***Hayes, J., Hampton, P. and **Manu, P**. (2011) Exploring the compliance of the fire safety order 2005 amongst micro/small organisations in England and Wales. In: Ruddock, L., Chynoweth, P. (Eds.), *Proceedings of the Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (COBRA)*, 12-13 September 2011, University of Salford, UK.

***Melrose, A., Hampton, P. and **Manu, P**. (2011) Safety at sports stadia. In: Lam, H.F. (Ed.), *Proceedings of Twelfth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-12)*, 26-28 January 2011, Hong Kong.

***Adukpo, E. S., Oteng-Seifah, S. **Manu, P**. (2011) Effect of oil coating on steel bar on the strength of reinforced concrete. In: Laryea, S., Leiringer, R., Hughes, W. (Eds.), *Proceedings of West Africa Built Environment Research (WABER) Conference*, 19-21 July 2011, Accra, Ghana.

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**Manu, P.**, Ankrah, N., Proverbs, D. and Suresh, S. (2010) Exploring the causal influence of construction project features in accident causation. In: Barrett, P., Amaratunga, D., Haigh, R., Keraminiyage, K., Pathirage, C. (Eds.), *Proceedings of CIB 2010 World Congress*, 10-13th May, Salford, UK.

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**Manu, P.**, Ankrah, N., Proverbs, D., Suresh, S. and Ahadzie, D. (2010) How and to what extent do construction project features contribute to accidents? Insight for accident prevention. In: Laryea, S., Leiringer, R., Hughes, W. (Eds.), *Proceedings of West Africa Built Environment Research (WABER) Conference*, 27-28 July, Accra, Ghana.

**Manu, P.**, Ankrah, N., Proverbs, D., Suresh, S. (2010) The extent of contribution of construction project features to accident causation and health and safety risk: a conceptual model. In: Egbu, C. (Eds.) *Proceedings of the 26th Annual Association of Researchers in Construction Management (ARCOM) Conference*, 6-8 September, Leeds, UK. Association of Researcher in Construction Management.

**Manu, P.**, Ankrah, N., Proverbs, D. and Suresh, S. (2010) An approach for evaluating the health and safety risk associated with construction project features based on their contribution to accident causation. In: *Proceedings of the Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (COBRA)*, 2-3 September, Paris. RICS.

***Manu, P**., Solomon-Ayeh, K. A., Hatfield, A. Adukpo, E. (2010) Using plastic in the form of ebonite strips as reinforcement bars in reinforced concrete beam. In: Barrett, P., Amaratunga, D., Haigh, R., Keraminiyage, K., Pathirage, C. (Eds.), *Proceedings of*

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*****Manu, P**., Phandey, R., and Proverbs, D, G. (2010) An investigation into the barriers towards making existing domestics properties more resilient to the effects of flooding: results of a case study. In: *Proceedings of the Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (COBRA)*, 2-3 September, Paris, RICS.

**Manu, P.**, Ankrah, N., Proverbs, D., Suresh, S. and Callaghan, E. (2009) Subcontracting versus health and safety: An inverse relationship. In: Lingard, H., Cooke, T., Turner, M. (Eds.), *Proceedings of CIB W099 2009 Conference, 21-23 October 2009*. RMIT. [This paper discusses an approach for evaluating the effectiveness of the Construction (Design and Management) Regulations 2007 in mitigating the adverse health and safety implications of subcontracting].

**Manu, P. A.**, Ankrah, N. A., Proverbs, D. and Suresh, S. (2009) Subcontracting versus health and safety: An inverse relationship. In: Ross, A. (Ed.) *Proceedings of Association of Researchers in Construction Management (ARCOM) Doctoral Workshop*, 12th May, School of Built Environment, Liverpool John Moores University. ARCOM. [This paper discusses the adverse health and safety implications of subcontracting].

***Book Chapters***

***Ankrah, N. A. and Manu, P. A. (2012) *Organisational culture and climate change driven construction*. *In:* Booth, C., Hammond, F., Lamond, J. and Proverbs, D. (Eds.) Solutions for climate change challenges of the built environment. West Sussex: Blackwell Publishing.

***These publications are not directly related to the research reported in this thesis, but were as a result of the overall research training and they were developed and published during the study period.

# Appendix B-1: Typical Invitation to Participate in Interview

Dear [Name],

**REQUEST FOR ASSISTANCE WITH RESEARCH INTO CONSTRUCTION HEALTH AND SAFETY**

In seeking to further advance its well established contribution to construction health and safety issues, the School of Technology, University of Wolverhampton is sponsoring this PhD research into construction accident causality with the particular focus on the involvement of pre-construction decisions. The research aims to deepen understanding of the contribution of pre-construction decisions by clients, designers and project management team to the causation of accidents on site. Such a study requires input from industry experts whose contribution will not only help make this research successful, but will also ensure that construction industry perspectives are central to the research and that the outcomes are reliable, relevant and responsive to ensuring the safety of construction workers and the public, and hence ensuring economic and social sustainability of construction organisations.

It is in the light of this that I am seeking the participation of a health and safety manager, site manager, construction manager, or project manager in your organisation, as a construction industry expert, to contribute to this research by way of participating in an interview which will take no more than an hour. For your assurance, the outcome of the interview will be in aggregated form and so there will be absolutely no reference to the interviewee or interviewee's organisation. Anonymity and confidentiality is therefore guaranteed. Also the interview will only seek to draw on the broad industrial experience and health and safety knowledge of the participant. In return for the assistance of your personnel, the findings of this research will be fed back to your organisation for consideration and further input.

This research is being undertaken under the supervision of Dr. Nii Ankrah, Professor David Proverbs and Dr. Subashini Suresh, who are established researchers in construction management at the School of Technology, University of Wolverhampton.

Attached to this letter is the interview schedule/questions for your study and should you be interested in participating in the interviews, please return the completed form in the enclosed self-addressed freepost envelope (no stamp required) or reply by a short email sent to the email address below stating based on your convenience, the date, time and venue (address) for the interview.

Counting on your consideration and support.

Yours faithfully,
Patrick A. Manu
Doctoral Research Student
School of Technology, University of Wolverhampton, WV1 1LY, Wolverhampton
Email: Patrick.Manu@wlv.ac.uk

## Appendix B-2: Interview Schedule

**Section A-** *Introduction*

1. Provide a brief profile; in particular your current position within your organisation, how long you have worked in the construction industry, and the nature and size of your organisation's operation.
2. How is your role related to ensuring safety on projects and what are some of the challenges in fulfilling that role?

**Section B-** *Construction accident causation: causes of accidents and path of causation*

1. How does your organisation manage health and safety?
2. In the occurrence of an accident/near miss how does your organisation respond in terms of its investigation and ensuring it does not recur?
3. What are some of the challenges involved in investigating the cause(s) of accidents/near misses?
4. When investigating the cause(s) of an accident/near miss does the investigation focus on the immediate circumstances leading to the accident/near miss or does the investigation also try to identify any underlying reasons behind those immediate circumstances?
5. Based on your broad experience and also from investigations, will you say that there are immediate (direct) causes of accidents as well as underlying/root causes behind (i.e. responsible for) the immediate causes?
6. Reflecting on your entire experience in construction, could you please narrate some near-miss incidents/accidents you have witnessed or have been involved in its investigation?
7. For each incident, could you mention the immediate and underlying causes?
8. From your experience, how easy is it to identify immediate and underlying causes of accidents?

**Section C-** *Construction accident causation: causal interactions*

1. Do causes of accidents sometimes act together/influence each other to give rise to accidents?

**Section D-** *Construction accident causation: the role of project characteristics/pre-construction decisions*

1. What are some of the health and safety (H&S) measures/controls implemented by your organisation on your projects to prevent accidents?
2. Concerning the mentioned H&S measure/controls, are they often generic measures (i.e. applied on all projects) or are they determined/influenced by the specific characteristics of each project such as the complexity of the design, the level of construction, the construction method, the procurement method, etc.
3. If the implemented H&S measures/controls are influenced by the specific characteristics of projects, could you please elaborate on these project characteristics and some of their respective H&S measures/controls?
4. From your broad experience, do you realise/see any influence/involvement of project characteristics such as complexity of the design, the level of construction, the construction method, the procurement method, etc. in the occurrence of accidents/near misses.
5. Would you classify the influence of the project characteristics in the occurrence of accidents/near misses as being immediate (direct) influence or root/underlying influence?

6. From your broad experience, do you see any influence/involvement of pre-construction decisions by clients (e.g. client's requirement) or project consultants (i.e. designers and project management team) in the occurrence of accidents?
7. Would you classify the influence/involvement of pre-construction decisions in the occurrence of accidents/near misses as being immediate (direct) influence or root/underlying influence?
8. Based on your broad experience, could you narrate any near misses/accidents which were influenced in a way by a pre-construction decision by a client or project consultants such as designers or project management team.

## Appendix C-1: Typical Cover Letter for Main Survey

Dear [Name]

**REQUEST FOR PARTICIPATION IN CONSTRUCTION HEALTH AND SAFETY RESEARCH**

I am Mr Patrick Manu, a PhD researcher at the School of Technology at the University of Wolverhampton and I would like to request for the participation of your organisation in a construction health and safety research which seeks to investigate the influence of construction projects characteristics in accident causation.

I would be very grateful if a health and safety manager, project manager, construction manager or site manager in your organisation can complete the enclosed questionnaire and return it in the self-addressed FREE POST (no stamp required) envelope. The questionnaire will take approximately 15 minutes to complete and it requires that the respondent reflects on his/her broad industrial experience to provide responses to the questions. In return for your organisation's participation, the findings of the research will be fed back to your company for consideration and further input.

In line with good research ethics, you are assured that the information obtained from this research will be kept strictly CONFIDENTIAL and used solely for research purposes.

This research is being undertaken under the supervision of Dr. Nii Ankrah and Dr. Subashini Suresh of the University of Wolverhampton, and Professor David Proverbs of the University of the West of England. If you require any further information or clarification, I will be happy to answer your questions. My contact details are below.

The research team do appreciate that the questionnaire will take some of the respondent's valuable time. However, without such expert input the intended contribution of this research towards improving construction health and safety will not be realised. It is our hope therefore that you will be able to assist in this research.

We are counting on your consideration and support.

Yours faithfully,

Patrick Manu
Doctoral Researcher
School of Technology, University of Wolverhampton
Wulfruna Street, Wolverhampton, WV1 1LY
Email: Patrick.Manu@wlv.ac.uk

## Appendix C-2: Questionnaire

UNIVERSITY OF WOLVERHAMPTON
KNOWLEDGE ▪ INNOVATION ▪ ENTERPRISE

*School of Technology*
*University of Wolverhampton*
*Wulfruna Street*
*Wolverhampton*
*WV1 1LY*

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**QUESTIONNAIRE ON CONSTRUCTION HEALTH AND SAFETY**

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**INFORMATION SHEET**

This survey is part of a doctoral research investigating the influence of construction project features in accident occurrence.

The questionnaire is in five sections. **Section A** requests background information. **Section B** focuses on the potential of features of construction projects to influence accident occurrence. **Section C** focuses on the potential of various site issues to influence accident occurrence. **Section D** examines the extent to which various site issues are common within project features. Finally, **Section F** requests general information.

Relying on your broad industrial experience, please answer all questions to the best of your ability. There are no "correct" or "incorrect" answers. Only your valued expert response is requested. The questionnaire will take approximately **15 minutes** to complete.

Please return the completed questionnaire using the self-addressed **free post (no stamps required)** envelope provided. If you have any questions or should you require/prefer an electronic version of the questionnaire please contact Mr Patrick Manu using the contact information below. Thank you very much for your time.

Patrick Manu
Doctoral Researcher
School of Technology
University of Wolverhampton
Wulfruna Street
Wolverhampton
WV1 1LY
Email: Patrick.Manu@wlv.ac.uk

**Section A:- Background Information**

1. Which of the following best describes your profession? Please tick [✓] only one box.

☐ Project manager ☐ Construction manager ☐ Site manager
☐ Health and safety manager ☐ Other. Please specify:___________________________________

2. How many years of experience do you have in this profession? Please specify: _____________________

3. In total, how many years of experience do you have in the construction industry? Please specify: _____

4. Are you a member of a professional organisation(s)? ☐ Yes ☐ No. If "Yes", please specify the organisation(s) name(s) and level of membership:_______________________________________________

5. Please specify your educational qualifications:________________________________________________

**Section B:- Project features: Potential to influence accident occurrence**

1. In the table below is a list of project features. Please rate by ticking [✓] the potential of each project feature to influence accident occurrence (0 = None, 1 = Low, 2 = Moderate, 3 = High, 4 = Very High).

| Project features | Potential to influence accident occurrence | | | | |
|---|---|---|---|---|---|
| | None 0 | Low 1 | Mod. 2 | High 3 | V. High 4 |
| 1. Refurbishment | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. Demolition | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. New work | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. Pre-assembly construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Traditional on-site construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. A restricted site (i.e. where footprint of facility covers most of the site area) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. An unrestricted site (i.e. where footprint of facility covers a small portion of the site area) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. A tight project duration | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. An adequate project duration | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. High-level construction (i.e. multi-level construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. Low-level construction (i.e. single-level construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. Underground construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. Complex design (i.e. design with intricate aesthetic qualities) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. Simple design (i.e. design with simple aesthetic qualities) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. Multi-layer subcontracting | ☐ | ☐ | ☐ | ☐ | ☐ |

| Project features | Potential to influence accident occurrence | | | | |
|---|---|---|---|---|---|
| | None 0 | Low 1 | Mod. 2 | High 3 | V. High 4 |
| 16. Single-layer subcontracting | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. Traditional method of procurement | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. Design and build procurement | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. Partnering procurement | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. Management contracting | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. Restricted site locality e.g. city centre location | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. Unrestricted site locality e.g. outer city location | ☐ | ☐ | ☐ | ☐ | ☐ |

**Section C:- Site Issues: Potential to influence accident occurrence**

1. In the table below is a list of site issues. Please rate by ticking [✓] the potential of each site issue to influence accident occurrence (0 = None, 1 = low, 2 = Moderate, 3 = High, 4 = Very High).

| Site issues | Potential to influence accident occurrence | | | | |
|---|---|---|---|---|---|
| | None 0 | Low 1 | Mod. 2 | High 3 | V. High 4 |
| 1. Uncertainty of hazards | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. Manual handling | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. Housekeeping problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. Time-pressure | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Site congestion | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. Mechanical handling | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. Fragmentation of project team | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. Difficulty in constructing (i.e. buildability) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. Working at height | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. Fragmentation of workforce | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. Working in confined space | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. Difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity | ☐ | ☐ | ☐ | ☐ | ☐ |

**Section D: Prevalence of site issues within project features**

1. Using the rating scale below please answer the following questions by ticking [✓].

0 = Not at all, 1 = low, 2 = Moderate, 3 = High, 4 = Very High.

| | Not at all 0 | Low 1 | Mod. 2 | High 3 | V. High 4 |
|---|---|---|---|---|---|
| 1. To what extent is *uncertainty of hazards* common within: | | | | | |
| a. Refurbishment | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Demolition | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. New work | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. To what extent is *working at height* common within: | | | | | |
| a. High-level construction (i.e. multi-level construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Low-level construction (i.e. single-level construction) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. To what extent is *fragmentation of workforce* common within: | | | | | |
| a. Single-layer subcontracting | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Multi-layer subcontracting | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. To what extent is *fragmentation of project team* common within: | | | | | |
| a. Traditional method of procurement | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Design and build procurement | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. Partnering procurement | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. Management contracting | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. To what extent is *manual handling* common within: | | | | | |
| a. Pre-assembly construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Traditional on-site construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. To what extent is *mechanical handling* common within: | | | | | |
| a. Pre-assembly construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Traditional on-site construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. To what extent is *housekeeping problems* common within: | | | | | |
| a. Pre-assembly construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Traditional on-site construction | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. To what extent is *time-pressure* common within: | | | | | |
| a. A tight project duration | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. An adequate project duration | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. To what extent is *working in confined space* common within: | | | | | |
| a. Underground construction | ☐ | ☐ | ☐ | ☐ | ☐ |

| | Not at all 0 | Low 1 | Mod. 2 | High 3 | V. High 4 |
|---|---|---|---|---|---|
| 10. To what extent is *site congestion* common within: | | | | | |
| a. A restricted site (i.e. where footprint of facility covers most of the site area) | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. An unrestricted site (i.e. where footprint of facility covers a small portion of the site area) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. To what extent is *difficulty in constructing (i.e. buildability)* common within: | | | | | |
| a. A complex design (i.e. design with intricate aesthetic qualities) | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. A simple design (i.e. design with simple aesthetic qualities) | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. To what extent is *difficulty in traffic (i.e. vehicle and pedestrian) control around site vicinity* common within: | | | | | |
| a. Restricted site locality e.g. city centre location | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Unrestricted site locality e.g. outer city location | ☐ | ☐ | ☐ | ☐ | ☐ |

**Section E: General Information**

Q1. If you have any comments about the influence of project features in accident occurrence or causes of accidents in general please specify in the space below.

Q2. Would you be interested in participating in a further phase of the research?

Please tick [✓] one option: ☐ Yes ☐ No

Q3. Would you be interested in receiving the research findings? Please tick [✓] one option: ☐ Yes ☐ No

Please provide your contact information if you answered “Yes” to Q2 or Q3.

| | |
|---|---|
| Name of respondent: | |
| Name of company: | |
| Company address: | |
| Email: | |
| Telephone: | |

**THIS IS THE END OF THE QUESTIONNAIRE. THANK YOU FOR YOUR TIME!**

**NOW, PLEASE RETURN THE QUESTIONNAIRE USING THE SELF-ADDRESSED ENVELOPE PROVIDED.**

## Appendix D: Pattern of Missing Data

| Item | N | Mean | Std. Dev. | Missing | | No. of Extremes[b] | | Summary of Estimated Means | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Count | % | Low | High | Listwise | EM | Regression |
| Exp_Role | 182 | 16.32 | 10.491 | 2 | 1.1 | | 6 | 16.11 | 16.30 | 16.22 |
| Exp_Industry | 182 | 24.12 | 12.194 | 2 | 1.1 | | | 24.38 | 24.31 | 24.12 |
| C_Refurb | 183 | 2.51 | .925 | 1 | .5 | 6 | | 2.53 | 2.52 | 2.52 |
| C_Demo | 184 | 3.17 | .954 | | .0 | 11 | | 3.18 | 3.17 | 3.17 |
| C_New | 181 | 1.98 | .745 | 3 | 1.6 | . | . | 2.00 | 1.99 | 1.98 |
| C_Preassembly | 180 | 1.53 | .773 | 4 | 2.2 | | 3 | 1.51 | 1.51 | 1.53 |
| C_Trad_Const | 184 | 2.22 | .658 | | .0 | 2 | | 2.18 | 2.22 | 2.22 |
| C_Rest_Site | 183 | 2.62 | .803 | 1 | .5 | 2 | | 2.63 | 2.61 | 2.61 |
| C_Unrest_Site | 183 | 1.80 | .790 | 1 | .5 | | 3 | 1.80 | 1.79 | 1.79 |
| C_T_Dura | 182 | 2.84 | .707 | 2 | 1.1 | 1 | | 2.86 | 2.84 | 2.84 |
| C_A_Dura | 183 | 1.66 | .731 | 1 | .5 | | 3 | 1.69 | 1.66 | 1.66 |
| C_HLConst | 182 | 2.74 | .888 | 2 | 1.1 | 5 | | 2.76 | 2.76 | 2.75 |
| C_LLConst | 183 | 1.71 | .740 | 1 | .5 | | 2 | 1.73 | 1.71 | 1.71 |
| C_UGConst | 183 | 2.84 | .897 | 1 | .5 | 5 | | 2.86 | 2.84 | 2.85 |
| C_Cdesign | 184 | 2.61 | .848 | | .0 | 5 | | 2.63 | 2.61 | 2.61 |
| C_Sdesign | 182 | 1.54 | .740 | 2 | 1.1 | | | 1.55 | 1.55 | 1.54 |
| C_MLSubcon | 182 | 2.70 | .788 | 2 | 1.1 | 3 | | 2.72 | 2.70 | 2.71 |
| C_SLSubcon | 182 | 1.63 | .731 | 2 | 1.1 | | 2 | 1.63 | 1.63 | 1.62 |
| C_TMProcure | 181 | 1.81 | .801 | 3 | 1.6 | | 3 | 1.82 | 1.81 | 1.80 |
| C_DBProcure | 182 | 1.84 | .776 | 2 | 1.1 | | 2 | 1.88 | 1.83 | 1.83 |
| C_PProcure | 179 | 1.78 | .761 | 5 | 2.7 | | 1 | 1.82 | 1.77 | 1.77 |
| C_MCProcure | 179 | 1.96 | .763 | 5 | 2.7 | . | . | 1.99 | 1.95 | 1.96 |
| C_RSL | 182 | 2.57 | .760 | 2 | 1.1 | 1 | | 2.60 | 2.57 | 2.57 |
| C_USL | 183 | 1.80 | .747 | 1 | .5 | | 3 | 1.80 | 1.80 | 1.80 |
| Uncertainty | 184 | 3.11 | .798 | | .0 | 4 | | 3.11 | 3.11 | 3.11 |
| ManHand | 183 | 2.23 | .757 | 1 | .5 | 1 | | 2.24 | 2.23 | 2.22 |
| HseKeeping | 183 | 2.59 | .735 | 1 | .5 | | | 2.63 | 2.59 | 2.59 |

| Item | N | Mean | Std. Dev. | Missing | | No. of Extremes[b] | | Summary of Estimated Means | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Count | % | Low | High | Listwise | EM | Regression |
| TimePress | 184 | 2.88 | .717 | | .0 | . | . | 2.91 | 2.88 | 2.88 |
| SiteCongest | 184 | 2.89 | .669 | | .0 | . | . | 2.91 | 2.89 | 2.89 |
| MechHan | 184 | 1.96 | .774 | | .0 | | 3 | 1.97 | 1.96 | 1.96 |
| FragPT | 184 | 2.40 | .747 | | .0 | 1 | | 2.43 | 2.40 | 2.40 |
| DiffConst | 184 | 2.65 | .767 | | .0 | | | 2.66 | 2.65 | 2.65 |
| WkgHeight | 184 | 2.91 | .780 | | .0 | 1 | | 2.93 | 2.91 | 2.91 |
| FragWF | 183 | 2.49 | .740 | 1 | .5 | | | 2.55 | 2.48 | 2.49 |
| WkgConf | 183 | 2.69 | .887 | 1 | .5 | 2 | | 2.69 | 2.69 | 2.69 |
| DiffTraffic | 184 | 2.83 | .748 | | .0 | | | 2.85 | 2.83 | 2.83 |
| Uncertainty_Refurb | 180 | 2.79 | .921 | 4 | 2.2 | 2 | | 2.79 | 2.77 | 2.79 |
| Uncertainty_Demo | 182 | 2.95 | .927 | 2 | 1.1 | | | 2.97 | 2.93 | 2.94 |
| Uncertainty_New | 182 | 1.62 | .739 | 2 | 1.1 | | 2 | 1.59 | 1.62 | 1.63 |
| WkgHeightHLConst | 182 | 3.19 | .848 | 2 | 1.1 | 7 | | 3.22 | 3.18 | 3.19 |
| WkgHeightLLConst | 182 | 1.98 | .889 | 2 | 1.1 | | | 1.97 | 1.98 | 1.98 |
| FragWFSLSub | 180 | 1.77 | .731 | 4 | 2.2 | | 4 | 1.78 | 1.77 | 1.78 |
| FragWFMLSub | 180 | 2.73 | .781 | 4 | 2.2 | 1 | | 2.74 | 2.73 | 2.74 |
| FragPTTradProc | 179 | 1.86 | .748 | 5 | 2.7 | | 3 | 1.89 | 1.86 | 1.86 |
| FragPTDBProc | 179 | 1.82 | .722 | 5 | 2.7 | | 1 | 1.83 | 1.81 | 1.81 |
| FragPTPProc | 178 | 1.83 | .772 | 6 | 3.3 | | 1 | 1.86 | 1.82 | 1.82 |
| FragPTMCProc | 178 | 2.01 | .713 | 6 | 3.3 | . | . | 2.04 | 2.02 | 2.00 |
| ManHandPreAss | 182 | 1.75 | .772 | 2 | 1.1 | | 2 | 1.72 | 1.75 | 1.74 |
| ManHandTradConst | 182 | 2.66 | .699 | 2 | 1.1 | | | 2.68 | 2.66 | 2.66 |
| MechHandPreAss | 182 | 2.41 | .922 | 2 | 1.1 | 3 | | 2.39 | 2.40 | 2.41 |
| MechHandTradConst | 182 | 2.32 | .728 | 2 | 1.1 | | | 2.30 | 2.32 | 2.33 |
| HseKeepPreAss | 182 | 1.63 | .803 | 2 | 1.1 | | 3 | 1.62 | 1.62 | 1.62 |
| HseKeepTradConst | 182 | 2.68 | .726 | 2 | 1.1 | 1 | | 2.68 | 2.68 | 2.68 |
| TimePresTDura | 182 | 3.14 | .679 | 2 | 1.1 | 3 | | 3.14 | 3.13 | 3.13 |
| TimePresADura | 182 | 1.79 | .715 | 2 | 1.1 | | 4 | 1.79 | 1.78 | 1.79 |

| Item | N | Mean | Std. Dev. | Missing | | No. of Extremes[b] | | Summary of Estimated Means | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Count | % | Low | High | Listwise | EM | Regression |
| WkgConUGCon | 181 | 2.93 | .867 | 3 | 1.6 | . | . | 2.97 | 2.92 | 2.92 |
| SiteConRsite | 182 | 3.05 | .719 | 2 | 1.1 | 4 | | 3.06 | 3.05 | 3.05 |
| SiteConUsite | 182 | 1.59 | .689 | 2 | 1.1 | | 2 | 1.62 | 1.60 | 1.60 |
| DiffConstCdesign | 182 | 2.91 | .756 | 2 | 1.1 | . | . | 2.91 | 2.90 | 2.91 |
| DiffConstSdesign | 182 | 1.43 | .650 | 2 | 1.1 | | | 1.41 | 1.44 | 1.43 |
| DiffTraffRSL | 182 | 3.08 | .701 | 2 | 1.1 | 3 | | 3.07 | 3.07 | 3.06 |
| DiffTraffUSL | 182 | 1.60 | .749 | 2 | 1.1 | | 1 | 1.62 | 1.61 | 1.61 |
| Role | 184 | | | | .0 | | | | | |
| Professional_membership | 179 | | | 5 | 2.7 | | | | | |
| Education | 162 | | | 22 | 12.0 | | | | | |
| Further_paticipation | 174 | | | 10 | 5.3 | | | | | |
| Interest_findings | 175 | | | 9 | 4.9 | | | | | |

a. Indicates that the inter-quartile range (IQR) is zero.

b. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

Little's MCAR test: Chi-Square = 1779.185, DF = 1765, Sig. = .402

## Appendix E-1: Research Report

*School of Technology*
*University of Wolverhampton*
*Wulfruna Street*
*Wolverhampton*
*WV1 1LY*

**DOCTORAL RESEARCH INTO CONSTRUCTION HEALTH AND SAFETY**

**REPORT ON INQUIRY INTO THE ACCIDENT CAUSAL INFLUENCE OF CONSTRUCTION PROJECT FEATURES**

Researcher : Patrick Manu

Supervisory Team: Dr Nii Ankrah, Professor David Proverbs and Dr Subashini Suresh

November 2011

**Introduction**

With several injuries, deaths and dangerous occurrences reported in the UK construction industry, the need to tackle the health and safety (H&S) challenges of the industry cannot be overstated. One of the key steps towards tackling these challenges has been the emphasis on early planning of H&S in project procurement. Central to the early planning of H&S is the need for project team members to pay attention to root causes of accidents that originate from the pre-construction stage. Construction project features (CPFs) such as method of construction, nature of project, site restriction, project duration, procurement method, design complexity, level of construction, and subcontracting have been reported as being among these root causes of accidents. Addressing the accident causal influence of CPFs requires detailed knowledge of how they influence accident occurrence, the degree of their inherent potential to influence accident occurrence (i.e. their potential to cause accident) and consequently their associated H&S risk (i.e. the likelihood of accident occurrence due to CPFs). This research was thus undertaken in pursuit of three objectives as follows:

1. To investigate how CPFs influence accident occurrence
2. To assess the potential of CPFs to influence accident occurrence, and consequently their associated H&S risk, and
3. To develop a simple H&S risk management toolkit that integrates the findings from the above objectives.

**Research Method**

A two-phase research strategy was adopted. The first phase which aimed to achieve the first objective involved in-depth interviews with 11 experienced construction professionals. The second phase which aimed to achieve the second objective involved a nation-wide questionnaire survey of construction organisations. Out of a 1,000 administered questionnaires, the survey yielded 184 valid responses (i.e. 18.4% response rate). The findings from the 2 phases are presented below.

**Findings**

**Phase 1**: It was found that:

- CPFs, being to a large extent the result of pre-construction decisions, are inherently associated with certain H&S issues (termed as *proximal accident factors* (PFs) shown in Table 1) which they introduce into the construction phase to cause accidents.

Table 1: Proximal accident factors associated with CPFs

| *CPFs* | *Proximal accident factors* |
|---|---|
| Nature of Project | Uncertainty of hazards |
| Method of Construction | Manual handling, Mechanical handling, and Housekeeping problems |
| Site Restriction | Site congestion |
| Project Duration | Time-pressure |
| Procurement method | Fragmentation of project team |
| Design Complexity | Difficulty in building (i.e. buildability) |
| Level of Construction | Working at height/ Working in confined space |
| Subcontracting | Fragmentation of workforce |
| Restriction of locality of site | Difficulty in traffic (vehicle and pedestrian) control around site vicinity |

- There are also causal interactions between CPFs and the PFs which can reduce or increase the presence of a PF.

These findings are summarised in the accident causation model shown in Figure1 below.

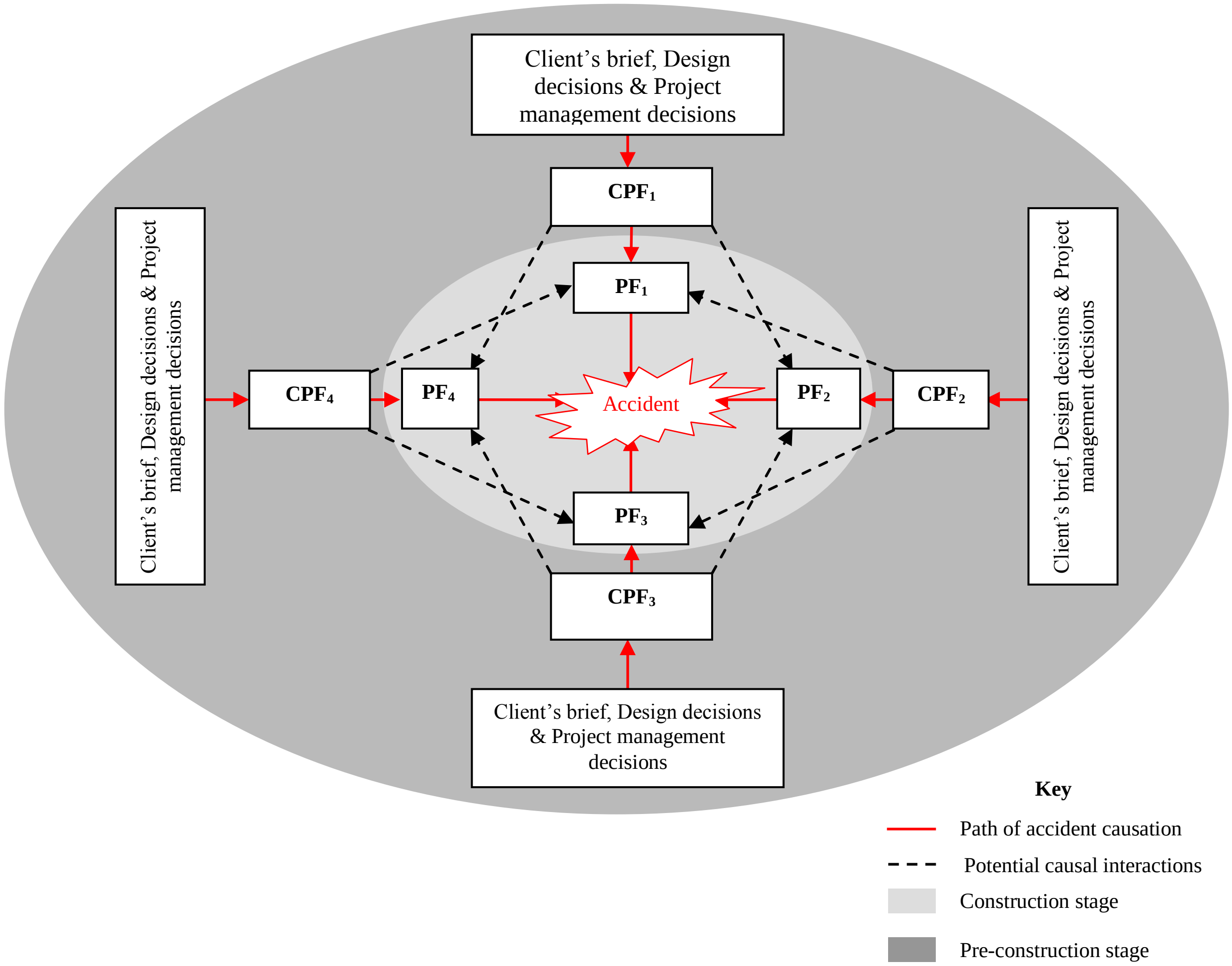


Figure 1: How construction project features influence accident occurrence.

**Phase 2**:

Part 1: Assessment of the potential of CPFs to influence accident occurrence and H&S risk associated with CPFs

The potential of CPFs to influence accident occurrence was assessed on a 5 point scale: None, Low, Moderate, High, and Very High. The risk associated with CPFs was subsequently assessed using a risk combination matrix based on the risk expression, *Risk associated with a CPF = Potential of the CPF to influence accident occurrence x Exposure of workforce to the CPF*. This expression was adapted from a common risk expression: Risk = Hazard (i.e. the inherent potential of something to cause harm) *x* Exposure. Exposure was considered in terms of whether or not a CPF applies to a project. The risk was assessed using a 5 point scale: No Risk, Low Risk, Medium Risk, High Risk, and Very High Risk. The *findings* of the assessment of the potential of CPFs to influence accident occurrence and risk associated with CPFs are presented in Table 2.

Part 2: Factors which influence the potential of CPFs to influence accident occurrence

The research also examined whether the degree of potential of a CPF to influence accident occurrence is related to two factors:

1. The extent to which its proximal factor(s) is common within the CPF, and
2. The potential of its proximal factor(s) to influence accident occurrence.

Table 2: Degree of potential of CPFs to influence accident occurrence and risk associated with CPFs

| CPFs | Potential to influence accident occurrence | | * H&S Risk associated with CPF | |
|---|---|---|---|---|
| | Moderate | High | Medium | High |
| 1. Demolition | | ✓ | | ✓ |
| 2. Underground construction | | ✓ | | ✓ |
| 3. Tight project duration | | ✓ | | ✓ |
| 4. High-level construction | | ✓ | | ✓ |
| 5. Multi-layer subcontracting | | ✓ | | ✓ |
| 6. Complex design | | ✓ | | ✓ |
| 7. Restricted site | | ✓ | | ✓ |
| 8. Restricted site locality | | ✓ | | ✓ |
| 9. Refurbishment | | ✓ | | ✓ |
| 10. Traditional on-site construction | ✓ | | ✓ | |
| 11. New work | ✓ | | ✓ | |
| 12. Management contracting | ✓ | | ✓ | |
| 13. Design and build procurement | ✓ | | ✓ | |
| 14. Traditional method of procurement | ✓ | | ✓ | |
| 15. Partnering procurement | ✓ | | ✓ | |
| 16. Pre-assembly construction | ✓ | | ✓ | |
| 17. Unrestricted site locality | ✓ | | ✓ | |
| 18. Unrestricted site | ✓ | | ✓ | |
| 19. Low-level construction | ✓ | | ✓ | |
| 20. Adequate project duration | ✓ | | ✓ | |
| 21. Single-layer subcontracting | ✓ | | ✓ | |
| 22. Simple design | ✓ | | ✓ | |

***Note: The risk assessment reflects the situation where a CPF applies to a project. Where a CPF does not apply to a project there is no risk due that CPF.**

It was found that:

- The potential of a CPF to influence accident occurrence is significantly related to the extent to which its proximal accident factor(s) is common within it.
- The potential of a CPF to influence accident occurrence is also significantly related to the potential of its proximal accident factor(s) to influence accident occurrence.

### H&S Risk Toolkit: A Consolidation of the Research Findings

The findings discussed above have been consolidated in a H&S risk management toolkit called "***CRiMT***". It provides information on how CPFs influence accident occurrence. It also allows the selection of CPFs that apply to a project and then presents in a unified format the H&S risk profile of the project. Additionally, the toolkit offers suggestions for controlling risk associated with the selected CPFs.

### Conclusion

The study has sought to provide insight into how CPFs influence accident occurrence, the degree of potential of CPFs to influence accident occurrence and the degree of H&S risk associated with CPFs. The findings provide empirical evidence that CPFs have varying degrees of H&S consequences associated with them. The findings also provide information that could equip pre-construction project participants (i.e. the project client, design team, project management team, and construction team) to manage these consequences early in project procurement. It is recommended that project participants who determine CPFs should opt for medium-risk CPFs as opposed to high-risk ones. Where this is not possible, project participants should implement measures to eliminate or reduce the presence of proximal factors introduced by CPFs or should implement measures to reduce the potential of those proximal factors to cause accident. ***CRiMT*** offers project participants the opportunity to do these by providing in a unified format the H&S risk profile of projects based on their features.

# Appendix E-2: Feedback Form

**RESEARCH FEEDBACK FORM**

Please provide comments on how valid the research findings are with regards to your experience. Respond to the questions below by checking [✓] one of the multiple choice options and also by providing your comments.

1. The research found that CPFs influence accident by their inherent introduction of health and safety issues (which can be termed as proximal accident factors) into the construction phase to give rise to accidents. To what extent do you agree with this finding?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Please provide any additional comments on the validity of the finding:

2. The research also found that there can be causal interactions between CPFs and proximal accident factors which can reduce or increase the presence of proximal accident factors. To what extent do you agree with this finding?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Please provide any additional comments on the validity of the finding:

3. Table 2 in the report indicates the findings of the assessment of the degree of potential of CPFs to influence accident occurrence (i.e. their potential to cause accident). From your experience, how valid is the assessment?

Please provide your response:

4. Table 2 in the report indicates the findings of the assessment of the degree of H&S risk associated with CPFs (i.e. the likelihood of accident occurrence due to CPFs). From your experience, how valid is the assessment?

Please provide your response:

5. The research found that the potential of a CPF to influence accident occurrence is significantly related to the extent to which its proximal accident factor(s) is common within it. To what extent do you agree with this finding?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Please provide any additional comments on the validity of the finding:

6. The research also found that the potential of a CPF to influence accident occurrence is significantly related to the potential of its proximal accident factor(s) to influence accident occurrence. To what extent do you agree with this finding?

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Please provide any additional comments on the validity of the finding:

The research findings have been consolidated in a H&S risk management toolkit which you are kindly requested to test and then provide some feedback. To start the toolkit, download and open the attached file, "***CRiMT***". After opening the file, kindly read the brief "***Introductory Note***" and then click on the button labelled "***CPFs***". After clicking this button, on the displayed page, **select the features of a recently completed project you have worked on** and then click on the button labelled, "***Proceed to >>>Risk Profile>>>***". Now please respond to the following feedback questions based on the "***Risk Profile***".

7. How similar is the risk profile to the H&S challenges and risk experienced on the project?

☐ Not Similar ☐ Slightly similar ☐ Fairly similar ☐ Similar ☐ Very similar

Please provide any additional comments:

If your organisation's operations include property development (e.g. housing development), please respond to all the remaining feedback questions. If not, please respond to only question 10.

8. At the concept/design stage of a new development how useful could risk information such as that provided by this tool be in terms of informing/influencing decisions that determine CPFs?

☐ Not useful ☐ Slightly useful ☐ Fairly useful ☐ Useful ☐ Very useful

Please provide any additional comments:

9. At the concept/design stage of a new development how useful could risk information such as that provided by this tool be in terms of informing/influencing the planning of design or project management solutions to control H&S risk posed by CPFs?

☐ Not useful ☐ Slightly useful ☐ Fairly useful ☐ Useful ☐ Very useful

Please provide any additional comments:

10. Any additional comments about the validity of the findings or the relevance of the toolkit to H&S risk management on projects?

Comments:

**Please return the completed feedback form by email as attachment to Patrick.Manu@wlv.ac.uk**

# Appendix E-3: Results of Respondent Validation

**Feedback Results**

| Question | Respondent | Feedback |
|---|---|---|
| 1. The research found that CPFs influence accident by their inherent introduction of health and safety issues (which can be termed as proximal accident factors) into the construction phase to give rise to accidents. To what extent do you agree with this finding? | 1 | Neutral |
| | 2 | Strongly agree |
| | 3 | Agree |
| | 4 | Agree |
| | 5 | Strongly agree |
| | 6 | Agree |
| | 7 | Agree |
| | 8 | Agree |
| | 9 | Agree |
| | 10 | Agree |
| | 11 | Agree |
| | 12 | Agree |
| | 13 | Agree |
| 2. The research also found that there can be causal interactions between CPFs and proximal accident factors which can reduce or increase the presence of proximal accident factors. To what extent do you agree with this finding? | 1 | Agree |
| | 2 | Strongly agree |
| | 3 | Agree |
| | 4 | Agree |
| | 5 | Agree |
| | 6 | Agree |
| | 7 | Agree |
| | 8 | Agree |
| | 9 | Neutral |
| | 10 | Agree |
| | 11 | Agree |
| | 12 | Agree |
| | 13 | Agree |
| 3. Table 2 in the report indicates the findings of the assessment of the degree of potential of CPFs to influence accident occurrence (i.e. their potential to cause accident). From your experience, how valid is the assessment? | 1 | The CPFs within table 2 are known to cause accidents within the construction industry. |
| | 2 | I agree - assessment is valid. |
| | 3 | I would agree CPFs influence potential accident occurrence. |
| | 4 | I think that having experienced site staff who will be aware of accidents can reduce/eliminate. |
| | 5 | These are very generic and I am not sure how much you can generalise what are specific. |
| | 6 | Acts as a checklist. |
| | 7 | Quite good - preassembly construction in my opinion would be lower than moderate. |
| | 8 | There are other risk to do with construction method than manual handling, mechanical handling, and housekeeping problems. What about confined space, working at height. |
| | 9 | Very valid dependant on many factors. |
| | 10 | Yes the factors reflect the situation that you are likely to find. |
| | 11 | I would agree, as certain types of design can lead to high risk activities i.e. it will look lovely when complete but no one has thought of how to build it. |
| | 12 | Valid |
| | 13 | Over the years, I have come across instances where the initial design has been poor which has led to design change being required during the construction phase. |

**Feedback Results (Cont'd)**

| Question | Respondent | Feedback |
|---|---|---|
| 4. Table 2 in the report indicates the findings of the assessment the health and safety risk associated with CPFs (i.e. the likelihood of accident occurrence due to CPFs). From your experience, how valid is the assessment? | 1 | Again these are known problem areas. |
| | 2 | I agree - assessment is valid. |
| | 3 | Generally I would agree with the assessment. |
| | 4 | Again risks are always there, each building has its own unique risks so it needs experienced people to spot them and put in controls. |
| | 5 | These appear to be generalising specific and complex relationships. |
| | 6 | Acts as a checklist. |
| | 7 | Quite good - I would class low level construction and pre-assembly lower than medium. |
| | 8 | There are other contributing factors to each element |
| | 9 | Fairly true again dependant of factors with the stakeholders. |
| | 10 | Yes the factors reflect the situation that you are likely to find. |
| | 11 | The more risk that is involved the more likely you are to have an accident on site, therefore the more complicated CPFs the more risk, so I agree with table. |
| | 12 | Valid |
| | 13 | Over the years, I have come across instances where the initial design has been poor which has led to design change being required during the construction phase. |
| 5. The research found that the potential of a CPF to influence accident occurrence is significantly related to the extent to which its proximal accident factor(s) is common within it. To what extent do you agree with this finding? | 1 | Agree |
| | 2 | Strongly agree |
| | 3 | Agree |
| | 4 | Agree |
| | 5 | Agree |
| | 6 | Agree |
| | 7 | Agree |
| | 8 | Neutral |
| | 9 | Agree |
| | 10 | Strongly agree |
| | 11 | Agree |
| | 12 | Agree |
| | 13 | Agree |
| 6. The research also found that the potential of a CPF to influence accident occurrence is significantly related to the potential of its proximal accident factor(s) to influence accident occurrence. To what extent do you agree with this finding? | 1 | Agree |
| | 2 | Strongly agree |
| | 3 | Agree |
| | 4 | Agree |
| | 5 | Agree |
| | 6 | Agree |
| | 7 | Agree |
| | 8 | Neutral |
| | 9 | Agree |
| | 10 | Strongly agree |
| | 11 | Agree |
| | 12 | Agree |
| | 13 | Agree |

**Feedback Results (Cont'd)**

| Question | Respondent | Feedback |
|---|---|---|
| 7. How similar is the risk profile to the H&S challenges and risk experienced on the project? | 1 | Very Similar |
| | 2 | Very Similar |
| | 3 | Similar |
| | 4 | Fairly similar |
| | 5 | Fairly similar |
| | 6 | (No response) |
| | 7 | Fairly similar |
| | 8 | Slightly similar (Some good points are covered, but the multi-causal effect on the various issues on a construction site mean that the data is limited). |
| | 9 | (No response) |
| | 10 | Similar |
| | 11 | Slightly similar (Gives some pointers from a generic point of view. It would be a good pointer for those more involved at the planning stage, prior to a main contractor coming on board.) |
| | 12 | Fairly similar |
| | 13 | Similar |
| 8. At the concept/design stage of a new development how useful could risk information such as that provided by this tool be in terms of informing/influencing decisions that determine CPFs? | 1 | Fairly useful |
| | 2 | Very useful |
| | 3 | Slightly useful |
| | 4 | (No response) |
| | 5 | (No response) |
| | 6 | Useful |
| | 7 | Fairly useful |
| | 8 | Fairly useful |
| | 9 | Very useful |
| | 10 | Useful |
| | 11 | (Not applicable) |
| | 12 | Fairly useful |
| | 13 | (Not applicable) |
| 9. At the concept/design stage of a new development how useful could risk information such as that provided by this tool be in terms of informing/influencing the planning of design or project management solutions to control H&S risk posed by CPFs? | 1 | Useful |
| | 2 | Very useful |
| | 3 | Slightly useful |
| | 4 | Useful |
| | 5 | Fairly useful |
| | 6 | Useful |
| | 7 | Fairly useful |
| | 8 | Fairly useful |
| | 9 | Very useful |
| | 10 | Fairly useful |
| | 11 | (Not applicable) |
| | 12 | Fairly useful |
| | 13 | (Not applicable) |

**Feedback Results (Cont'd)**

| Question | Respondent | Feedback |
|---|---|---|
| 10. Any additional comments about the validity of the findings or relevance of the toolkit to H&S risk management on projects? | 1 | (No response) |
| | 2 | Your research has reinforced guidance as detailed in the Construction Design & Management Regulations 2007 which legislates all aspects of construction from - 'cradle to grave' (i.e. construction through to eventual demolition). |
| | 3 | I found the toolkit to be an interesting way to consider and assess hazard potential. I think the controls need reviewing to make a truly useful toolkit to industry. |
| | 4 | (No response) |
| | 5 | (No response) |
| | 6 | I hope the sample used was large enough to give accurate information. |
| | 7 | (No response) |
| | 8 | Again, it's a good effort but the multi-disciplinary nature of most construction sites and the sheer number of issues to be considered means that the limitations of a short academic project would not allow all of the issues to be incorporated. |
| | 9 | Appropriate and relevant to this very complex industry. |
| | 10 | I think the users would be looking for drop down control 'hierarchical lists'. |
| | 11 | (No response) |
| | 12 | (No response) |
| | 13 | (No response) |

**Respondents Information**

| *Respondents ID* | *Role* | *Years of Experience in Construction* |
|---|---|---|
| 1 | H&S Manager | 9 |
| 2 | Construction H&S Consultant | 15 |
| 3 | H&S Manager | 22 |
| 4 | Business Improvement Manager | 40 |
| 5 | Construction Manager | 13 |
| 6 | H&S Manager | 25 |
| 7 | H&S Manager | 9 |
| 8 | H&S Manager | 9 |
| 9 | Construction H&S Consultant | 30 |
| 10 | H&S Manager | 30 |
| 11 | H&S Manager | 30 |
| 12 | Construction Manager | 30 |
| 13 | H&S Manager | 30 |

## Appendix F: H&S Risk Profile of CPFs

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of Potential of Proximal Factor to Influence Accident Occurrence | Degree to which Proximal Factor is Common/Prevalent within CPF | Degree of Potential of CPF to Influence Accident Occurrence | Degree of H&S Risk Associated with CPF (i.e. Likelihood of Accident Occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Demolition | Uncertainty of hazards | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid demolition through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce uncertainty of hazards. (3) Implement measures to reduce the potential of uncertainty of hazards to cause accidents. |
| Refurbishment | Uncertainty of hazards | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid refurbishment through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce uncertainty of hazards. (3) Implement measures to reduce the potential of uncertainty of hazards to cause accidents |
| New work | Uncertainty of hazards | High | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce uncertainty of hazards. (2) Implement measures to reduce the potential of uncertainty of hazards to cause accidents. |
| High-level construction | Working at height | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid high-level construction through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce working at height. (3) Implement measures to reduce the potential of working at height to cause accidents. |

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of Potential of Proximal Factor to Influence Accident Occurrence | Degree to which Proximal Factor is Common/Prevalent within CPF | Degree of Potential of CPF to Influence Accident Occurrence | Degree of H&S Risk Associated with CPF (i.e. Likelihood of Accident Occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Low-level construction | Working at height | High | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce working at height. (2) Implement measures to reduce the potential of working at height to cause accidents. |
| Underground construction | Working in confined space | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid underground construction through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce working in confined space. (3) Implement measures to reduce the potential of working in confined space to cause accidents. |
| Complex Design | Difficulty in constructing i.e. buildability | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid complex design (i.e. design with intricate aesthetic qualities). Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce difficulty in constructing (i.e. buildability). (3) Implement measures to reduce the potential of difficulty in constructing (i.e. buildability) to cause accidents. |
| Simple Design | Difficulty in constructing i.e. buildability | High | Low | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce difficulty in constructing (i.e. buildability). (2) Implement measures to reduce the potential of difficulty in constructing (i.e. buildability) to cause accidents. |

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of Potential of Proximal Factor to Influence Accident Occurrence | Degree to which Proximal Factor is Common/Prevalent within CPF | Degree of Potential of CPF to Influence Accident Occurrence | Degree of H&S Risk Associated with CPF (i.e. Likelihood of Accident Occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Restricted site locality e.g. city centre | Difficulty in traffic control around site vicinity | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid restricted site locality through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce difficulty in traffic control around site vicinity. (3) Implement measures to reduce the potential of difficulty in traffic control around site vicinity to cause accidents. |
| Unrestricted site locality e.g. outer city | Difficulty in traffic control around site vicinity | High | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce difficulty in traffic control around site vicinity. (2) Implement measures to reduce the potential of difficulty in traffic control around site vicinity to cause accidents. |
| Pre-assembly construction | Manual handling | Moderate | Moderate | Moderate | Moderate | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce manual handling and housekeeping problems. (2) Implement measures to reduce the potential of manual handling, housekeeping problems, and mechanical handling to cause accidents. |
| | Mechanical handling | Moderate | High | | | | |
| | Housekeeping problems | High | Moderate | | | | |
| Traditional on-site construction | Manual handling | Moderate | High | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce manual handling and housekeeping problems. (2) Implement measures to reduce the potential of manual handling, housekeeping problems, and mechanical handling to cause accidents. |
| | Mechanical handling | Moderate | Moderate | | | | |
| | Housekeeping problems | High | High | | | | |

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of Potential of Proximal Factor to Influence Accident Occurrence | Degree to which Proximal Factor is Common/Prevalent within CPF | Degree of Potential of CPF to Influence Accident Occurrence | Degree of H&S Risk Associated with CPF (i.e. Likelihood of Accident Occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Tight project duration | Time-pressure | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid tight project duration through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce time-pressure. (3) Implement measures to reduce the potential of time-pressure to cause accidents. |
| Adequate project duration | Time-pressure | High | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce time-pressure. (2) Implement measures to reduce the potential of time-pressure to cause accidents. |
| Design and build procurement | Fragmentation of project team | Moderate | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce fragmentation of project team. (2) Implement measures to reduce the potential of fragmentation of project team to cause accidents. |
| Traditional procurement | Fragmentation of project team | Moderate | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce fragmentation of project team. (2) Implement measures to reduce the potential of fragmentation of project team to cause accidents. |
| Management contracting | Fragmentation of project team | Moderate | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce fragmentation of project team. (2) Implement measures to reduce the potential of fragmentation of project team to cause accidents. |

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of Potential of Proximal Factor to Influence Accident Occurrence | Degree to which Proximal Factor is Common/Prevalent within CPF | Degree of Potential of CPF to Influence Accident Occurrence | Degree of H&S Risk Associated with CPF (i.e. Likelihood of Accident Occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Partnering | Fragmentation of project team | Moderate | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce fragmentation of project team. (2) Implement measures to reduce the potential of fragmentation of project team to cause accidents. |
| Multi-layer subcontracting | Fragmentation of workforce | Moderate | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid multi-layer subcontracting through decision-making at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce fragmentation of workforce. (3) Implement measures to reduce the potential of fragmentation of workforce to cause accidents. |
| Single-layer subcontracting | Fragmentation of workforce | Moderate | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce fragmentation of workforce. (2) Implement measures to reduce the potential of fragmentation of workforce to cause accidents. |
| Restricted site (i.e. where footprint of facility covers most of site area) | Site congestion | High | High | High | High | Substantial efforts should be made to reduce risk to as low as reasonably practicable | (1) If possible avoid restricted site at the concept/design stage. Note that this will not be viable if this project feature is inevitable, for instance due to client/project requirement. (2) Implement measures to eliminate or reduce site congestion. (3) Implement measures to reduce the potential of site congestion to cause accidents. |

| Construction Project Features (CPFs) | Proximal Factor Associated with CPF | Degree of Potential of Proximal Factor to Influence Accident Occurrence | Degree to which Proximal Factor is Common/Prevalent within CPF | Degree of Potential of CPF to Influence Accident Occurrence | Degree of H&S Risk Associated with CPF (i.e. Likelihood of Accident Occurrence due to CPF) | Acceptability of Degree of Risk * | Suggested Risk Control Measures |
|---|---|---|---|---|---|---|---|
| Unrestricted site (i.e. where footprint of facility covers a small portion of the site area) | Site congestion | High | Moderate | Moderate | Medium | Efforts should be made to reduce risk to as low as reasonably practicable | (1) Implement measures to eliminate or reduce site congestion. (2) Implement measures to reduce the potential of site congestion to cause accidents. |